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Survey of Projects Concerning Conventional Combustion Environmental Assessments

Interagency Energy/Environment R&D Program Report

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16. ABSTRACT

The report summarizes information on activities relating to the environmental assessment of stationary conventional combustion processes. The information was gathered on a nationwide basis and includes activities sponsored by government, industry, universities, and trade associations. Many abstracts of such work are given in the report. The information obtained was analyzed to determine its significance relative to a planning, coordination, and implementation plan being developed for EPA. The report includes the RTI input to the first annual report on EPA's Conventional Combustion Environmental Assessment Program.

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Contract No. 68-02-2612
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Office of Research and Development
Washington, DC 20460

ABSTRACT

This report summarizes information on activities relating to the environmental assessment of stationary conventional combustion processes (SCCP). The information was gathered on a nationwide basis and includes activities sponsored by government, industry, universities, and trade associations. Many abstracts of such work are given in this report. The information obtained was analyzed to determine its significance relative to the planning, coordination, and implementation plan being developed for EPA by MITRE Corporation. This report includes the Research Triangle Institute (RTI) input to the first annual report on the conventional combustion environmental assessment program.

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FOREWORD

In January 1977, IERL/RTP established the Conventional Combustion Environmental Assessment (CCEA) program under the direction of the Utilities and Industrial Power Division. A major objective of the first year of the program was to study and evaluate the current conventional combustion work of the Laboratory and other organizations in order to formulate methods for guiding and coordinating the future work of the Laboratory in this area.

As a part of the overall program, the Research Triangle Institute was assigned two major goals:

- to survey, evaluate, and report Conventional Combustion Environmental Assessment related projects being carried out by government, industry, trade organizations, and universities.
- to prepare parts of the First Annual Conventional Combustion Environmental Assessment Report.

This report describes the work carried out to meet the above goals.

John K. Burchard
Director
IERL/RTP

SECTION 1

INTRODUCTION

The Research Triangle Institute (RTI) was given a work assignment to obtain information with as much detail as possible on activities, sponsored by government, industrial, and other organizations, related to the environmental assessment of conventional combustion processes. This information was analyzed to determine its significance relative to the planning, coordination, and implementation of a comprehensive Environmental Protection Agency (EPA) program for the environmental assessment of conventional combustion processes. The data and analyses were reported to the EPA Project Officer and to the MITRE Corporation, which was charged, under a separate work assignment, with the responsibility for overall program planning and implementation. In addition, RTI was to assist the MITRE Corporation in the preparation of the first annual report of Conventional Combustion Environmental Assessment (CCEA) activities.

This report summarizes RTI activities in meeting the objectives of the work assignment in Section 2, briefly describes the nature of the outputs from these activities in Section 3, and presents, in the Appendixes, RTI's input to MITRE for the first annual report on CCEA activities, following the detailed outline dictated by MITRE.

2.0 ACTIVITIES

Activities performed under this work assignment are summarized under the headings of information collection, engineering analysis, and coordination in this section. These were all performed in parallel during the course of the assignment.

Information Collection

Information on the scope and some of the details of CCEA research activity was collected by various methods: telephone contacts, a computer data base literature search, published project inventory data, contractor reports, and technical discussions with researchers at symposia or at their respective institutions. These sources and their characteristics are discussed briefly in this section and more completely in Appendix A.

Telephone Contacts--

Initially a number of telephone calls were made to organizations that, based on RTI's past experience, were known to be performing CCEA-related work. However, telephone calls were found to be a poor method of eliciting any details. Later the telephone was used only to request specific pieces of information or to arrange technical meetings.

Literature Searches--

All literature searches were carried out for RTI by the North Carolina Science and Technology Research Center (a NASA Industrial Applications Center). The information produced was then evaluated by RTI technical personnel for relevance. From searches, approximately 450 citations were selected as being relevant. Summaries of these results are given in Appendix C. The sources for the search are shown in Table 1.

TABLE 1. DATA FILES SEARCHED FOR PAST CCEA RESEARCH ACTIVITY

Data base name	Subject and source	Coverage from	Number of citations
Engineering Index (Compendex)	Worldwide engineering literature (3,500 publications)	1970	500,000
Energy Data Base	Complete energy information (ERDA)	1974	100,000
Pollution	Pollution and environment (pollution abstracts)	1970	37,700
Smithsonian Science Information Exchange (SSIE)	Research projects in progress; emphasizes federally funded projects and includes many privately funded projects (Smithsonian Science Information Exchange)	1966	200,000

ERDA Inventory--

A considerable amount of information was obtained from the publication Inventory of Federal Energy-Related Environment and Safety Research for FY1976 - ERDA 7750, Volume 1 of 4.

This document provides overviews of federally funded, energy-related environment and safety research projects. The four volumes summarize some 2,500 projects of which about 150 were identified as relevant to the CCEA program. Some of these summaries appear in Appendix A.

EPRI--

A visit was made to the Electric Power Research Institute (EPRI) where technical discussions were held with several program directors. These provided an overview of the very extensive research programs being carried out under EPRI funding. Some idea of the magnitude of this effort can be obtained by considering the proposed 1977-1981 EPRI budget, shown in Table 2. For example, the proposed combined expenditures in fossil fuel controls and environmental assessments over the 5-year period amount to about $143 million, or 13 percent of the entire EPRI budget for the period. Some of EPRI's research efforts are briefly described in Appendix A.

EPRI plans to spend approximately $1 billion in electric generation research over the next 5 years. They estimate that 50 percent of this budget will be relevant to combustion pollution. Considering the magnitude of this effort, it seems imperative that the IERL/RTP CCEA Program establish improved coordination with EPRI.

Symposia--

Two symposia were attended during the course of the project. These were the Second Stationary Source Combustion Symposium, July 1977, and the Symposium on Flue Gas Desulfurization, November 1977. From the two symposia a broad perspective on work on emissions assessments and control methods was obtained.

Reports were prepared from the papers presented in support of both the CCEA plan and the First Annual Report. Descriptions of some of the projects covered in the symposia appear in Appendix A. Symposia were judged to be an efficient and inexpensive means of collecting project information.

TABLE 2. EPRI SUMMARY OF PROPOSED PROGRAM PLAN ($ MILLIONS)*

PROGRAM	1977	1978	1979	1980	1981	Total
FOSSIL FUEL AND ADVANCED SYSTEMS						
Fluidized combustion and coal cleaning	4.8	8.1	8.8	9.4	10.0	41.1
Air quality control	14.3	10.2	10.2	10.4	10.8	55.9
Water quality control and heat rejection	1.9	2.4	2.6	2.6	2.7	12.2
Fossil plant performance and reliability	2.4	2.8	3.0	4.1	4.4	16.8
TOTAL - Fossil fuel power plants	23.4	23.5	24.6	26.5	27.9	126.0
Clean gaseous fuels	11.1	9.5	10.0	10.0	10.0	50.5
Clean liquid and solid fuels	14.9	14.8	14.5	14.5	14.5	73.3
Power generation	5.8	7.0	7.5	9.5	10.5	40.3
Power plant requirements and analysis	0.7	1.0	1.0	1.0	1.0	4.7
TOTAL - Advanced fossil power systems	32.5	32.3	33.0	35.0	36.0	168.9
Fusion	4.7	3.4	3.8	4.3	4.4	20.6
Solar	4.4	3.4	3.7	4.0	4.3	19.8
Geothermal	2.2	2.0	2.0	2.2	2.3	10.7
TOTAL - New energy resources	11.3	8.8	9.5	10.5	11.0	51.1
Energy storage	5.2	7.1	9.0	8.9	8.2	38.3
Fuel cells and chemical energy conversion	9.0	8.5	6.7	6.6	7.8	38.7
Energy utilization and conservation technology	1.0	1.4	2.3	2.5	3.0	10.1
TOTAL - Energy management and utilization technology	15.2	17.0	18.0	18.0	19.0	87.1
TOTAL - FOSSIL FUEL AND ADVANCED SYSTEMS	82.4	81.6	85.1	90.0	93.9	433.0
NUCLEAR POWER						
Water reactor systems technology	14.8	18.8	17.9	18.0	17.9	87.4
Reliability, availability, and economics	14.1	16.4	16.9	16.0	13.9	77.3
Fuels, waste, and environment	8.0	9.0	9.7	10.7	12.2	49.6
Developing application and technology	9.1	7.0	9.0	11.8	15.0	51.9
TOTAL - NUCLEAR POWER	46.0	51.2	53.5	56.5	59.0	266.2
ELECTRICAL SYSTEMS						
AC transmission	7.0	7.5	7.9	8.3	8.7	39.4
Underground transmission	7.5	7.5	8.0	8.4	8.8	40.2
DC transmission	10.9	4.4	3.9	4.0	4.2	27.4
Distribution	5.2	6.4	6.7	7.3	7.6	33.2
Systems planning, security, and control	1.9	2.7	2.9	3.1	3.2	13.8
Rotating electrical machinery	0.5	2.8	3.2	3.4	3.5	13.4
TOTAL - ELECTRICAL SYSTEMS	33.0	31.3	32.6	34.5	36.0	167.4
ENERGY ANALYSIS AND ENVIRONMENT						
Environmental assessment	10.4	12.5	14.8	17.0	20.1	74.8
Demand and conservation	2.1	2.7	2.6	2.6	2.6	12.2
Supply	3.1	3.8	3.7	3.7	3.7	18.0
Systems	1.5	1.6	1.7	1.7	1.7	8.2
Electric utility rate design study	.8	.3	-	-	-	.3
TOTAL - ENERGY ANALYSIS AND ENVIRONMENT	17.9	20.9	22.8	25.0	28.1	114.7
TOTAL FUNDS ALLOCATED	179.3	185.0	194.0	206.0	217.0	981.3
Nonprogrammed expenditure	-	5.0	9.0	28.0	61.0	103.0
TOTAL INSTITUTE	179.3	190.0	203.0	234.0	278.0	1,084.3

*Funding entries represent planned contractor expenditures stated in current dollars including an adjustment for inflation.

Other--

Work plans, monthly project reports, interim reports, and final reports were all used extensively. However, the most detailed information was gathered by visits to various organizations involved in CCEA research for direct discussions with the researchers.

One of the most significant information-gathering activities was to identify and list, from an Industrial Environmental Research Laboratory (IERL) Management Information System printout of current projects, those which pertained to CCEA. From this list, subsequently, a group of about 25 projects were selected in joint meetings with MITRE personnel and the EPA Project Officer to obtain programmatic information for MITRE's analysis in their Program Management scheme for the CCEA Program. This information was developed through interviews with IERL Project Officers to fill out special forms devised by MITRE (later revised by RTI).

Engineering Analysis

Very early in the course of work on this assignment discussions were held with personnel of the Process Measurements Branch of the Industrial Processes Divison of IERL. The position of PMB/IPD was that projects acquiring environmental assessment data could be compared for overlap or gaps only by a detailed analysis which included information on:

1. The specific source types being considered,
2. The points in the process at which samples were being taken,
3. The sampling procedures used, and
4. The analysis procedures used.

Preliminary forms were designed to elicit this information from Project Leaders, Project Officers, and others. However, these forms were not used, due to several reasons.

First, there was a problem of combustion source type classification. At least two different classification schemes were in use in major IERL projects. Neither of these used the standard NEDS source classification code. This problem is discussed in detail in Appendix A.

Secondly, from the beginning of the project, one of the major questions was: What constitutes an "environmental assessment"? This was answered by the MITRE Corporation by using the methodology shown in Figure 1 as the basis for classifying project activity. The key features of this classification scheme were transposed by MITRE to the form shown in Figure 2. This was used by RTI in structuring and reporting contacts with CCEA researchers at IERL and elsewhere.

A third reason for not using the more detailed forms was that the level of information needed to fill them out placed a large time burden on both the interviewer and interviewee and developed information that probably would not be used in the comparative analysis and program structuring exercises of MITRE. Furthermore, in the initial efforts to grasp the extent and nature of CCEA activity throughout the country, such detail was probably not justified.

Therefore, the problems of devising a usable source classification scheme and suitable forms for structuring and reporting the specifics of project sampling and analysis schemes were left to follow-on efforts, as necessary.

The results of a computer-based literature search to determine the extent of recent CCEA activity were analyzed as presented in Appendix C. Since this was planned for inclusion in the first annual report on CCEA activities and it was desired to give a balanced view of prior IERL research on CCEA, Appendix C also includes a detailed list of reports of prior IERL work grouped into the categories:

Reports on Emissions Characterization, Measurement Methodology, and Measurements;

Reports on SO_2 Control Processes;

Reports on NO_x Control Processes;

Reports on Particulate Matter Control Properties;

Reports on Economic, Energy, and Resource Recovery or Conservation Factors; and

Reports on Multi-Media Impacts and Goals.

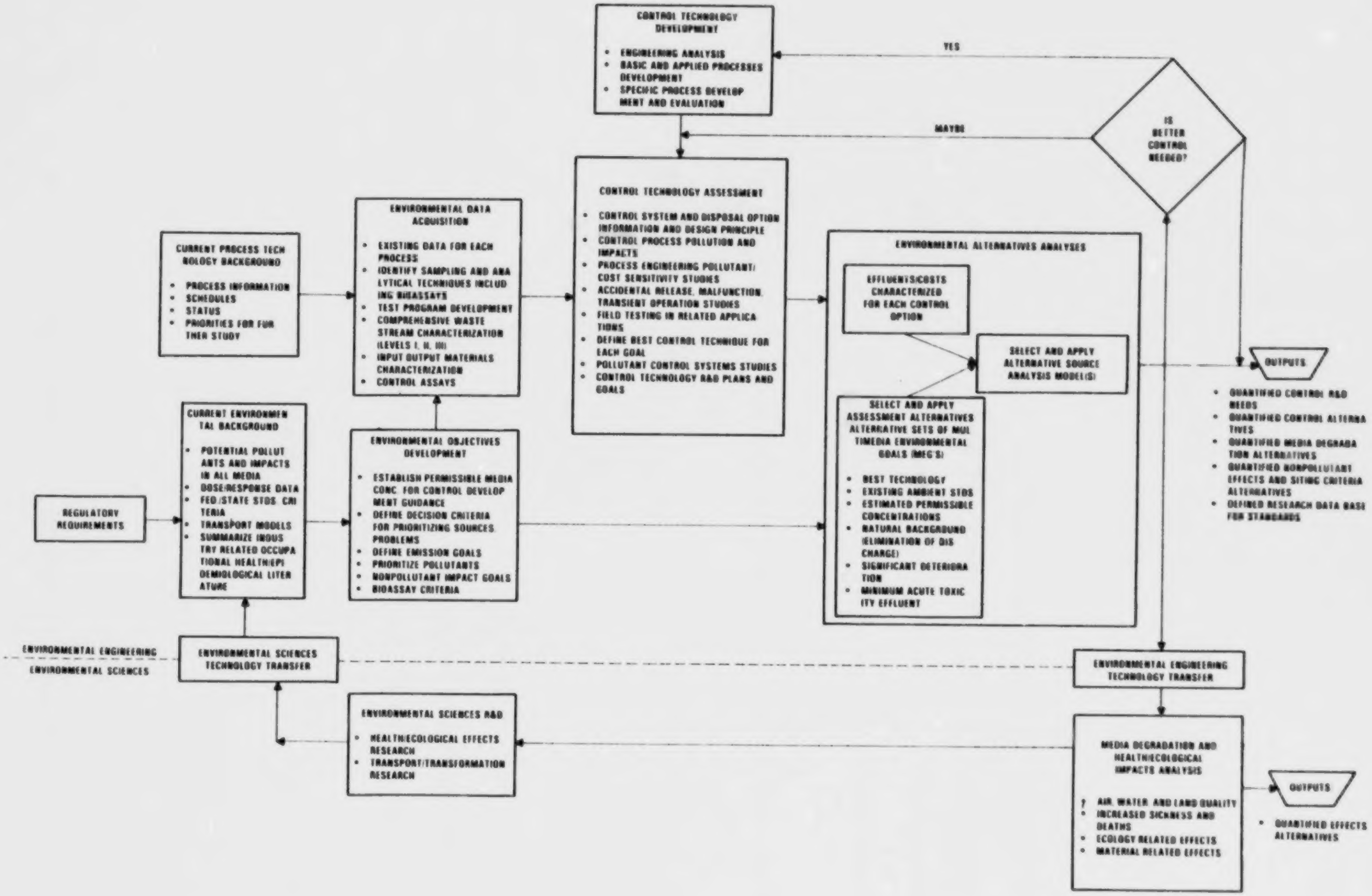
CONTROL TECHNOLOGY DEVELOPMENT
• ENGINEERING ANALYSIS
• BASIC AND APPLIED PROCESSES DEVELOPMENT
• SPECIFIC PROCESS DEVELOPMENT AND EVALUATION
YES
MAYBE
IS BETTER CONTROL NEEDED?
CURRENT PROCESS TECHNOLOGY BACKGROUND
• PROCESS INFORMATION
• SCHEDULES
• STATUS
• PRIORITIES FOR FURTHER STUDY
ENVIRONMENTAL DATA ACQUISITION
• EXISTING DATA FOR EACH PROCESS
• IDENTIFY SAMPLING AND ANALYTICAL TECHNIQUES INCLUDING BIOASSAYS
• TEST PROGRAM DEVELOPMENT
• COMPREHENSIVE WASTE STREAM CHARACTERIZATION (LEVELS I, II, III)
• INPUT OUTPUT MATERIALS CHARACTERIZATION
• CONTROL ASSAYS
CONTROL TECHNOLOGY ASSESSMENT
• CONTROL SYSTEM AND DISPOSAL OPTION INFORMATION AND DESIGN PRINCIPLE
• CONTROL PROCESS POLLUTION AND IMPACTS
• PROCESS ENGINEERING POLLUTANT/COST SENSITIVITY STUDIES
• ACCIDENTAL RELEASE, MALFUNCTION, TRANSIENT OPERATION STUDIES
• FIELD TESTING IN RELATED APPLICATIONS
• DEFINE BEST CONTROL TECHNIQUE FOR EACH GOAL
• POLLUTANT CONTROL SYSTEMS STUDIES
• CONTROL TECHNOLOGY R&D PLANS AND GOALS
ENVIRONMENTAL ALTERNATIVES ANALYSES
EFFLUENTS/COSTS CHARACTERIZED FOR EACH CONTROL OPTION
SELECT AND APPLY ALTERNATIVE SOURCE ANALYSIS MODEL(S)
SELECT AND APPLY ASSESSMENT ALTERNATIVES ALTERNATIVE SETS OF MULTIMEDIA ENVIRONMENTAL GOALS (MEG'S)
• BEST TECHNOLOGY
• EXISTING AMBIENT STDS
• ESTIMATED PERMISSIBLE CONCENTRATIONS
• NATURAL BACKGROUND (ELIMINATION OF DISCHARGE)
• SIGNIFICANT DETERIORATION
• MINIMUM ACUTE TOXICITY EFFLUENT
OUTPUTS
• QUANTIFIED CONTROL R&D NEEDS
• QUANTIFIED CONTROL ALTERNATIVES
• QUANTIFIED MEDIA DEGRADATION ALTERNATIVES
• QUANTIFIED NONPOLLUTANT EFFECTS AND SITING CRITERIA ALTERNATIVES
• DEFINED RESEARCH DATA BASE FOR STANDARDS
REGULATORY REQUIREMENTS
CURRENT ENVIRONMENTAL BACKGROUND
• POTENTIAL POLLUTANTS AND IMPACTS IN ALL MEDIA
• DOSE/RESPONSE DATA
• FED/STATE STDS CRITERIA
• TRANSPORT MODELS
• SUMMARIZE INDUSTRY RELATED OCCUPATIONAL HEALTH/EPIDEMIOLOGICAL LITERATURE
ENVIRONMENTAL OBJECTIVES DEVELOPMENT
• ESTABLISH PERMISSIBLE MEDIA CONC. FOR CONTROL DEVELOPMENT GUIDANCE
• DEFINE DECISION CRITERIA FOR PRIORITIZING SOURCES PROBLEMS
• DEFINE EMISSION GOALS
• PRIORITIZE POLLUTANTS
• NONPOLLUTANT IMPACT GOALS
• BIOASSAY CRITERIA
ENVIRONMENTAL ENGINEERING
ENVIRONMENTAL SCIENCES
ENVIRONMENTAL SCIENCES TECHNOLOGY TRANSFER
ENVIRONMENTAL ENGINEERING TECHNOLOGY TRANSFER
ENVIRONMENTAL SCIENCES R&D
• HEALTH/ECOLOGICAL EFFECTS RESEARCH
• TRANSPORT/TRANSFORMATION RESEARCH
MEDIA DEGRADATION AND HEALTH/ECOLOGICAL IMPACTS ANALYSIS
? AIR, WATER AND LAND QUALITY
• INCREASED SICKNESS AND DEATHS
• ECOLOGY RELATED EFFECTS
• MATERIAL RELATED EFFECTS
OUTPUTS
• QUANTIFIED EFFECTS ALTERNATIVES

Figure 1. Environmental assessment/control technology development diagram.

PROGRAM: ____

____

DURATION: ____________________ PROGRAM MANAGER: ____________________

CONTRACTOR: ____________________ PROJECT OFFICER: ____________________

CONTRACT #: ____________________ ANSWERS RECORDED BY: ____________________

FUNDING: ____________________ DATE: ____________________

A. CURRENT PROCESS TECHNOLOGY BACKGROUND

1 - This program will identify sources and gather information on:

- Processes (list specific processes; for example, opposed wall fired burner, IC, engine, stoker):

- Fuels (bituminous, lignite, residual oil, refuse, etc.):

- Use sector: utility ☐ , residential ☐ , commercial ☐ , industrial ☐

B. CURRENT ENVIRONMENTAL BACKGROUND

1 - This program will identify ☐ potential pollutants and ☐ impacts of pollutants.

- The pollutants of major concern are:

- The pollutants of secondary concern are:

Figure 2. MITRE form for CCEA projects (sheet 1 of 5).

- Analytical Methods and Instruments:

- The media area investigated in the program are:

2 - This program ☐ identifies (☐ develops) sources of data for pollutant dose/health ☐ and ecological ☐ response for the given pollutants (if not for all pollutants and media given above, list appropriate pollutants):

3 - This program identifies ☐ actual and ☐ proposed standards for the following pollutants and media:

4 - This program ☐ identifies existing (☐ or develops) transport/fate models (list pollutants/media if not the same as those identified in B1):

5 - This program ☐ identifies (☐ or develops) industrial related occupational health epidemiological data (if not the same as listed in B1, please list):

C. ENVIRONMENTAL OBJECTIVES DEVELOPMENT

1 - This program ☐ does (☐ does not) define criteria for ranking of:

☐ processes or sources

☐ pollutants

2 - This program ranks ☐ processes and ☐ pollutants (list):

Figure 2 (sheet 2 of 5).

3 - This program ☐ does (☐ does not) define emission goals for:

☐ processes (list if not same as A1)

☐ pollutants (list if not same as B1)

4 - This program defines nonpollutant impact goals (energy, economics, commercial development).

☐ Yes ☐ No

5 - This program ☐ defines (☐ does not define) bioassay criteria.

6 - This program does ☐ , does not ☐ establish (☐ use previously established) permissible media concentrations for control development guidance for pollutants.

D. ENVIRONMENTAL DATA ACQUISITION

1 - This program will ☐ identify and/or ☐ develop all ☐ , some ☐ , ☐ sampling and ☐ analysis techniques (including ☐ bioassay) for pollutants from the given processes.

2 - This program ☐ develops (☐ does not develop) a test program and outline procedures for waste stream characterization:

and ☐ conducts comprehensive screening, ☐ performs level 1 measurements

☐ conducts detailed analysis, ☐ performs level 2 measurements

☐ conducts continuous monitoring of selected pollutants, ☐ performs level 3 measurements

(list selected pollutants if determined):

Comment:

3 - This program ☐ develops (☐ utilizes existing) input/output material characterization for given processes (performs material balance ☐):

Figure 2 (sheet 3 of 5).

4 - This program ☐ develops (☐ does not develop) bioassay data to evaluate effectiveness of controls on process streams (if different from A1, list):

5 - This program ☐ identifies data gaps

☐ designs a program to develop required data

☐ develops required data.

Comment:

E. CONTROL TECHNOLOGY ASSESSMENT

1 - This program will evaluate ☐ control process effectiveness, ☐ pollution by the control process, and ☐ disposal options (tradeoffs).

2 - This program ☐ will (☐ will not) study process control economics.

3 - This program ☐ will (☐ will not) investigate transient operation ☐ , malfunctions ☐ , and accidental release possibilities ☐ within the processes and control processes.

Comment/qualification:

4 - This program ☐ will determine when field test is required and ☐ perform the testing in related areas for the control processes.

Comment/qualification:

5 - This program ☐ will (☐ will not) complete or take part in control system demonstration programs.

6 - This program will define ☐ plans and ☐ goals for the control technologies and identify optimum control methods to meet these goals.

7 - This program ☐ will (☐ will not) investigate the impact of nonpollutant parameters (economic, energy, aesthetics) and their effects on the processes and control technologies.

Comment:

Figure 2 (sheet 4 of 5).

F. ENVIRONMENTAL ALTERNATIVES AND OUTPUTS

1 - This program ☐ will (☐ will not) characterize effluents and costs for the control options.

Comment/qualification:

2 - This program ☐ will (☐ will not) select and apply media degradation alternatives (alternative sets of effluent standards based on background, health, and ecological effects and technology). Please list actual basis for alternatives if known:

3 - Comparison of analytical models for control alternatives for all media, based on technology, costs, nonpollutant constraints, and multimedia environmental goals ☐ will (☐ will not) be made.

Comment/qualification:

4 - The results of this program will:

☐ quantify control R & D needs

☐ quantify control alternatives

☐ quantify media degradation alternatives

☐ quantify nonpollutant effects and site selection criteria

☐ define research data base for standards.

Comment (if the above do not apply to those areas identified in A1, B1, and E1, please qualify):

Figure 2 (sheet 5 of 5).

Based on the information obtained on current activities through the methods discussed in Section 2, a summary of these activities, grouping projects into the following categories, was prepared for the annual report:

Multi-Source Emissions Measurements;
Emissions Measurements on Utility Sources;
Emissions Measurements on Industrial Sources;
Emissions Measurements on Commercial, Institutional, and Residential Sources;
Fuel Characterization;
Measurement Methods;
Transport and Fate of Pollutants;
Health Effects;
Ecological Effects;
Multi-Media Goals;
Economic and Energy Factors;
SO_2 Control Technology;
NO_x Control Technology;
Particle Control Technology; and
Thermal Pollution Control.

This summary is reproduced in Appendix D.

Appendix A of this report reproduces Chapter VI, "Current Studies Related to Impacts of Pollutants," and Chapter VII, "Current Studies Related to Control Technology," which were submitted to MITRE and EPA for inclusion in the annual report. This appendix presents detailed discussions of ongoing CCEA project activity showing that many organizations in addition to IERL are investing considerable resources in such research and that the current effort by IERL to carefully coordinate and plan its CCEA activities is indeed timely.

In order to provide perspective on the laws and regulations pertaining to conventional combustion sources, a summary of existing and proposed regulations was prepared for inclusion in the annual report. This summary is reproduced in Appendix B.

Coordination

Throughout the course of this work assignment a determined effort was made to keep the EPA Project Officer and MITRE personnel informed. The

MITRE forms, shown in Figure 2, were forwarded as completed. In addition, many narrative trip reports and other contact reports were compiled and submitted. Although it was appreciated that the detail of many of these required a great deal of time on the part of the reader, it was felt that such details were necessary to bring out the broad scope and nuances of CCEA activities. Comprehending and managing research activities of the broad range of disciplines and phenomena encompassed in the methodology of Figure 1 is a very demanding task.

In addition to written reports, the EPA Project Officer was kept informed by telephone and short meetings of the highlights of the survey activity. Longer meetings to coordinate RTI activities with those of MITRE were held periodically by the EPA Project Officer. These offered many opportunities for constructive discussions as to what courses of action should be taken and provided opportunities for the EPA Project Officer to adjust priorities and redirect efforts as necessary.

APPENDIX A

CURRENT STUDIES RELATED TO IMPACTS OF POLLUTANTS AND CONTROL TECHNOLOGY

APPENDIX A*

VI. CURRENT STUDIES RELATED TO IMPACTS OF POLLUTANTS

A. GENERAL INTRODUCTION

The information contained in Sections VI and VII (and Appendixes B, C, and D) was obtained as part of an approximately 6-month study by RTI. The objective was to identify organizations conducting work on at least one of the elements of combustion pollution assessment. It was not known at the beginning of our study how extensive the work on CCEA was, however, it was soon apparent that a relatively large number of organizations were performing such work. Although many have been identified, no pretense is made of completeness. The RTI work needs to be extended with the objective of producing as complete a compendium of CCEA-related work as possible and also to store the information obtained in a computer system which can be readily updated.

Section VI gives typical examples of current work by some of the organizations studying the impacts of pollutants and Section VII surveys some of the research work in control technology. By no means are all of the organizations identified discussed in these two sections. Rather, typical examples are chosen to illustrate the types of relevant work being carried out on a broad front. More complete listings of the organizations and projects identified may be found in Appendixes C and D.

B. INFORMATION COLLECTION

Information on the scope and some of the details of CCEA research activity was collected by various methods: telephone contacts, a computer data base literature search, published project inventory data, contractor reports, and technical discussions with researchers at symposia or at their respective institutions. These sources and their characteristics are discussed briefly in this section.

1. Telephone Contacts

Initially a number of telephone calls were made to organizations that, based on RTI's past experience, were known to be performing CCEA-related work. However, telephone calls were found to be a poor method of eliciting any details. Later the telephone was used only to request specific pieces of information or to arrange technical meetings.

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*Sections VI and VII of the CCEA Annual Report are reproduced here as Appendix A.

2. Literature Searches

All literature searches were carried out by the North Carolina Science and Technology Research Center (a NASA Industrial Applications Center). The literature information produced was then evaluated by RTI technical people for relevance. From searches, approximately 450 citations were selected as being relevant. Summaries of these results are shown in Appendix C. The sources for the search are shown in Table VIB-1.

3. ERDA Inventory

Most of the following information has been abstracted from the publication Inventory of Federal Energy-Related Environment and Safety Research for FY1976 - ERDA 7750, Volume 1 of 4.

The purpose of the inventory is to provide a data base for providing overviews of federally funded, energy-related environment and safety research projects. The inventory can be used to assist planning for future research by aiding in the determination of the adequacy of current environmental, health, and safety research programs to meet the needs of developing energy technology.

The Energy Reorganization Act of 1974, PL93-438 authorizes the administrator of the Energy Research and Development Administration (ERDA) to establish programs to minimize the adverse environmental effects of energy development and utilization. It further directs that these programs will utilize research and development efforts supported by other Federal agencies in a cooperative manner to avoid unnecessary duplication.

A comprehensive plan was required to be submitted to Congress by the Federal Non-Nuclear Energy Research and Development Act of 1974, PL93-577, Section VI.

The inventory complies with these requirements.

The FY1976 inventory was improved over those of FY1974 and FY1975 by standardization and computerization of the data input. The requested information was expanded to include environmental control technology.

A questionnaire was developed to obtain uniform descriptive material for the inventory (OMB Form 294). To obtain as complete an inventory as possible, all Federal agencies likely to be involved in energy-related environment, health, and safety research programs were contacted.

Fourteen Federal agencies responded to the questionnaires to provide information for the inventory. They are limited to research conducted during

TABLE VIB-1. DATA FILES SEARCHED FOR PAST CPA RESEARCH ACTIVITY

Data base name	Subject and source	Coverage from	Number of citations
Engineering Index (compendex)	Worldwide engineering literature (3,500 publications)	1970	500,000
Energy Data Base	Complete energy information (ERDA)	1974	100,000
Pollution	Pollution and environment (pollution abstracts)	1970	37,700
Smithsonian Science Information Exchange SSIE	Research projects in progress; emphasizes federally funded projects and includes many privately funded projects (Smithsonian Science Information Exchange)	1966	200,000

FY1976. Table VIB-2 gives the names of the agencies, the number of projects for each agency, and the FY1976 funding level for research for the total dollars spent on research in biomedical and environmental research, environmental control technology, and operational safety. About 84 percent of the total Federal funding is represented by the sum of the budgets of ERDA, NRC, EPA, and DOC.

The following data are presented to show the distribution of research efforts in the field of biomedical and environmental research (BER). The category is divided into five subcategories: (1) characterization, measurement, and monitoring; (2) environmental transport, physical and chemical processes, and effects; (3) health effects; (4) ecological processes and effects; and (5) integrated assessment. Table VIB-3 gives the technology funding distribution for each of these five subcategories. Note that ERDA funding dominates all five categories. Table VIB-4 shows the breakdown of funding by technology areas for projects on environmental control technology. Note that EPA dominates the fossil fuel area and ERDA the nuclear area.

The four volumes of the ERDA inventory summarize approximately 2,500 projects, of which approximately 150 were identified as relevant. Some of the summaries appear in Sections VI and VII while more complete listings appear in Appendix C.

4. EPRI

A visit was made to the Electric Power Research Institute (EPRI) where technical discussions were held with several program directors. These provided an overview of the very extensive research programs being carried out under EPRI funding. Some idea of the magnitude of this effort can be obtained by considering the proposed 1977-1981 EPRI budget, shown in Table VIB-5. For example, the proposed combined expenditures in fossil fuel controls and environmental assessments over the 5-year period amount to about $143 million, or 13 percent of the entire EPRI budget for the period. Some of EPRI's research efforts are briefly described in Sections VI and VII and many projects are tabulated in Appendix D.

EPRI plans to spend approximately $1 billion in electric generation research over the next 5 years. They estimate that 50 percent of this budget will be relevant to combustion pollution. Considering the magnitude of this

TABLE VIB-2. FEDERAL AGENCY RESPONSES

Agency	No. of projects reported	Funding by agency (in millions)
Department of Agriculture (DOA)	7	$ 7.6
Department of Commerce (DOC)	93	41.0
Department of Defense (DOD)	3	1.4
Department of Health, Education, and Welfare (HEW)	263	22.6
Department of Housing and Urban Development (HUD)	1	*
Department of the Interior (DOI)	80	25.9
Department of Transportation (DOT)	9	.4
Environmental Protection Agency (EPA)	305	63.0
Energy Research and Development Administration (ERDA)	1,467	197.5
Federal Energy Administration (FEA)	20	1.7
National Science Foundation (NSF)/RANN	18	1.2
National Aeronautics and Space Administration (NASA)	5	1.3
Nuclear Regulatory Commission (NRC)	200	77.5
Tennessee Valley Authority (TVA)	65	11.8
Total	2,536	452.9

*Less than $0.05M

TABLE VIB-3. BIOMEDICAL AND ENVIRONMENTAL RESEARCH SUBCATEGORY FUNDING BY FEDERAL AGENCY, FY 1976 ($ in millions)

Energy technology	BER subcategory					Total
	Characterization, measurement, and monitoring	Environmental transport	Health effects	Ecological effects	Integrated assessment	
DOA	0.3	0.8	–	1.8	0.9	3.8
DOC:						
OEA	–	–	–	–	0.2	0.2
NBS	1.9	*	0.1	*	–	2.0
NOAA	4.3	8.5	0.2	19.0	6.3	38.2
DOD	–	–	–	–	–	–
HEW:						
NIOSH	0.9	–	1.0	–	–	1.9
NIEHS	*	*	13.2	0.5	0.1	13.8
NCI	–	–	6.7	–	–	6.7
HUD	–	–	–	–	*	*
DOI:						
FWS	0.2	–	–	2.3	*	2.5
BLM	–	–	–	–	–	–
USGS	7.4	4.2	–	2.5	3.6	17.8
RECLAM	0.1	–	–	0.1	–	0.2
BPA	*	*	–	*	0.3	0.4
DOT	0.1	–	*	–	–	0.1
EPA	5.6	1.9	4.6	3.9	3.1	19.1
ERDA	20.8	21.3	78.4	19.6	13.7	153.8
FEA	0.2	0.1	*	0.2	1.1	1.6
NSF/RANN	0.2	0.3	*	0.3	0.2	1.1
NASA	0.2	0.2	*	0.1	0.1	0.6
NRC	1.6	3.5	0.6	0.7	1.0	7.4
TVA	1.2	1.3	*	1.9	1.5	5.9
Total	45.1	42.1	104.8	52.9	32.1	277.1

*Less than $0.05M.

TABLE VIB-4. ENVIRONMENTAL CONTROL TECHNOLOGY FUNDING (ENERGY TECHNOLOGY BY FEDERAL AGENCY), FY 1976 ($ in millions)

Agency	Technology															
	Fossil general	Coal	Oil and gas	Oil shale	Bio-mass	Nuclear general	Fission	Fusion	Geo-thermal	Solar	Hydro-electric	Conser-vation	Multi-tech	General science	Other	Total
DOA	2.9	0.5	–	0.2	–	0.1	–	–	–	–	–	–	–	–	–	3.7
DOC:																
OEA	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
NBS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
NOAA	–	–	0.1	–	–	–	–	–	–	*	*	*	–	–	–	0.2
DOD	0.1	–	–	–	–	–	–	–	–	–	–	1.3	–	–	–	1.4
HEW:																
NIOSH	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
NIEHS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
NCI	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
HUD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
DOI:																
FWS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BLM	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
USGS	–	2.8	0.3	0.3	–	–	–	–	–	–	–	0.2	–	0.4	0.1	4.1
RECLAM	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BPA	–	*	*	–	–	–	–	–	–	–	0.1	–	–	–	–	0.1
DOT	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–	–	0.1
EPA	3.5	27.7	3.3	0.8	0.9	*	–	–	0.4	0.4	–	2.6	3.1	0.4	0.7	43.9
ERDA	0.1	2.4	1.1	0.1	–	30.5	0.7	0.2	0.7	*	–	0.3	0.5	0.2	0.2	36.9
FEA	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
NSF/RANN	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	*
NASA	–	0.2	–	*	–	–	–	–	*	–	–	–	0.4	–	–	0.7
NRC	–	–	–	–	–	1.3	*	–	–	–	–	–	–	–	–	1.3
TVA	0.8	4.0	–	–	–	–	–	–	–	–	0.1	0.5	–	0.3	*	5.7
Total	7.4	37.6	4.7	1.5	0.9	32.0	0.7	0.2	1.1	0.4	0.2	5.0	4.1	1.3	1.1	98.2

*Less than $0.05 M.

TABLE VIB-5. EPRI SUMMARY OF PROPOSED PROGRAM PLAN ($ MILLIONS)*

PROGRAM	1977	1978	1979	1980	1981	Total
FOSSIL FUEL AND ADVANCED SYSTEMS						
Fluidized combustion and coal cleaning	4.8	8.1	8.8	9.4	10.0	41.1
Air quality control	14.3	10.2	10.2	10.4	10.8	55.9
Water quality control and heat rejection	1.9	2.4	2.6	2.6	2.7	12.2
Fossil plant performance and reliability	2.4	2.8	3.0	4.1	4.4	16.8
TOTAL - Fossil fuel power plants	23.4	23.5	24.6	26.5	27.9	126.0
Clean gaseous fuels	11.1	9.5	10.0	10.0	10.0	50.5
Clean liquid and solid fuels	14.9	14.8	14.5	14.5	14.5	73.3
Power generation	5.8	7.0	7.5	9.5	10.5	40.3
Power plant requirements and analysis	0.7	1.0	1.0	1.0	1.0	4.7
TOTAL - Advanced fossil power systems	32.5	32.3	33.0	35.0	36.0	168.9
Fusion	4.7	3.4	3.8	4.3	4.4	20.6
Solar	4.4	3.4	3.7	4.0	4.3	19.8
Geothermal	2.2	2.0	2.0	2.2	2.3	10.7
TOTAL - New energy resources	11.3	8.8	9.5	10.5	11.0	51.1
Energy storage	5.2	7.1	9.0	8.9	8.2	38.3
Fuel cells and chemical energy conversion	9.0	8.5	6.7	6.6	7.8	38.7
Energy utilization and conservation technology	1.0	1.4	2.3	2.5	3.0	10.1
TOTAL - Energy management and utilization technology	15.2	17.0	18.0	18.0	19.0	87.1
TOTAL - FOSSIL FUEL AND ADVANCED SYSTEMS	82.4	81.6	85.1	90.0	93.9	433.0
NUCLEAR POWER						
Water reactor system technology	14.8	18.8	17.9	18.0	17.9	87.4
Reliability, availability, and economics	14.1	16.4	16.9	16.0	13.9	77.3
Fuels, waste, and environment	8.0	9.0	9.7	10.7	12.2	49.6
Developing application and technology	9.1	7.0	9.0	11.8	15.0	51.9
TOTAL - NUCLEAR POWER	46.0	51.2	53.5	56.5	59.0	266.2
ELECTRICAL SYSTEMS						
AC transmission	7.0	7.5	7.9	8.3	8.7	39.4
Underground transmission	7.5	7.5	8.0	8.4	8.8	40.2
DC transmission	10.9	4.4	3.9	4.0	4.2	27.4
Distribution	5.2	6.4	6.7	7.3	7.6	33.2
Systems planning, security, and control	1.9	2.7	2.9	3.1	3.2	13.8
Rotating electrical machinery	0.5	2.8	3.2	3.4	3.5	13.4
TOTAL - ELECTRICAL SYSTEMS	33.0	31.3	32.6	34.5	36.0	167.4
ENERGY ANALYSIS AND ENVIRONMENT						
Environmental assessment	10.4	12.5	14.8	17.0	20.1	74.8
Demand and conservation	2.1	2.7	2.6	2.6	2.6	12.2
Supply	3.1	3.8	3.7	3.7	3.7	18.0
Systems	1.5	1.6	1.7	1.7	1.7	8.2
Electric utility rate design study	.8	.3	-	-	-	.3
TOTAL - ENERGY ANALYSIS AND ENVIRONMENT	17.9	20.9	22.8	25.0	28.1	114.7
TOTAL FUNDS ALLOCATED	179.3	185.0	194.0	206.0	217.0	981.3
Nonprogrammed expenditure	-	5.0	9.0	28.0	61.0	103.0
TOTAL INSTITUTE	179.3	190.0	203.0	234.0	278.0	1084.3

*Funding entries represent planned contractor expenditures stated in current dollars including an adjustment for inflation.

effort, it seems imperative that the IERL/RTP CPA Program establish an improved coordination with EPRI.

5. Symposia

Two symposia were attended during the course of the project. These were The Second Stationary Source Combustion Symposium, July 1977, and the Symposium on Flue Gas Desulfurization, November 1977. From the two symposia a broad perspective on work on emissions assessments and control methods was obtained.

From the papers presented we were able to prepare numerous Mitre forms in support of both the CPA plan and the First Annual Report. Descriptions of some of the projects covered in the symposia appear in Sections VI and VII.

6. Other

Work plans, monthly project reports, interim reports, and final reports have all been used extensively. However, the most detailed information was gathered by visits to various organizations involved in CPA research for direct discussions with the researchers.

C. DESCRIPTION OF BURNER TYPES

The types of sources considered under the heading of "conventional combustion sources" are briefly described in this section for the reader who may not be familiar with the terminology used. It is convenient to divide the discussion according to the use sectors of utility and the combined grouping of industrial, commercial/institutional, and residential. The utility sources constitute the largest fuel consumption, much of which is coal, and therefore the largest pollution potential.

1. Utility Boilers

The utility boiler category encompasses all field-erected water tube boilers with a generating capacity of about 25 MW or more. This includes the vast majority of field-erected boilers used for electric power generation.

Fuels used in utility boilers include pulverized bituminous, subbituminous, and lignite coals; residual and crude oil; and natural gas. Coals are burned in either dry bottom or wet bottom furnaces. Dry bottom furnaces operate at combustion temperatures below the ash fusion point and ash is removed as a solid. Wet bottom furnaces melt the ash and remove slag through a bottom tap. Wet bottom furnaces are no longer being manufactured due to operational problems with low sulfur coals and because their high combustion temperatures promote NO_x formation.

The major combustion-related difference between boilers in this sector is furnace design, which leads to differences in emission characteristics. The primary burners/furnace configurations and their manufacturers are:

- Single-wall firing: Foster Wheeler Energy Corporation (FW), Babcock and Wilcox Company (B&W), and Riley Stoker Corporation (RS)
- Opposed-wall firing: B&W, FW, and RS
- Tangential-firing: Combustion Engineering, Inc. (CE)

In single-wall firing furnaces, burners are mounted normal to a furnace wall. These units are typically limited in capacity to about 400 MW because of furnace wall area. Use of these boilers is being phased out as a result of recent trends toward boilers with larger capacity.

When larger capacity is required, horizontally opposed wall-firing furnaces are normally used. In horizontally opposed wall-firing furnaces, burners are mounted on opposite furnace walls. This is the most recently developed firing configuration, and is found on the newer units.

Individual burners on single and opposed wall units are usually of the register type, with up to 72 burners mounted on the furnace walls. The pulverized coal is entrained by about 20 percent of the primary air and introduced into the combustion chamber at a velocity of about 25 m/s where turbulent mixing with the remainder of the combustion air occurs. Natural gas is injected at velocities up to sonic through nozzles located in the register throat. Residual oil is preheated and injected through atomizers using high pressure steam or mechanical means. For all of these fuels, secondary preheated air enters at speeds of about 60 m/s for oil and gas and about 37 m/s for pulverized coal.

In a tangential furnace, arrays of fuel and air nozzles are located at the same elevation in each of the four corners of the combustion chamber. Each nozzle is directed tangentially to a small firing circle in the center of the chamber. The resulting spin of the four flames creates high turbulence and thorough mixing of fuel and air in the combustion zone. Additional levels of nozzles are mounted 2 to 3.5 m apart in larger capacity furnaces.

Three other firing methods exist but are seldom encountered in new units. These are discussed below.

Cyclone furnaces were originally developed by B&W to burn low ash fusion temperature Illinois coal, and they have recently been used successfully with lignite. In this design, fuel and air are introduced circumferentially into the water-cooled cyclone furnace to produce the highly swirling, high temperature flame. The cyclone furnace must operate at high combustion temperatures since it is designed to operate as a slagging furnace. Since high temperatures result in high thermal NO_x formation, the cyclone furnace has lost its market and is seldom encountered in new units.

Vertical-firing furnaces were developed for pulverized coal before the advent of water-walled combustion chambers. They were used to a limited degree to fire anthracite coal. Anthracite, because of its low volatile content, is difficult to burn in conventional boilers. The long residence time resulting from the downward firing pattern in vertical furnaces was effective in achieving ignition and char burnout for anthracite. With the decline of anthracite as a utility fuel, vertical furnaces are no longer sold and few are found in the field.

Stoker-fired furnaces are also seldom found in the field primarily due to trends toward larger capacity boilers. Design capacity limitations and high costs have prevented widespread use of stokers in utility boilers.

In Section VI, the above three firing types are grouped together under the heading of Other.

The distribution of utility boilers by firing type and fuel for the year 1974 is shown in Figure VIC-1. The totals listed were derived from a systems study by GCA and a boiler inventory by Battelle. Note that over 86 percent of the number of installed boilers is represented by wall-fired boilers and tangentially fired boilers. Since Figure VIC-1 is based on the number of installed units of each design type, it does not accurately reflect the distribution by installed capacity.

Figure VIC-2 shows the distribution by installed capacity for coal-fired boilers. Note that wall-fired and tangentially fired units account for approximately 90 percent of the coal consumed by utility boilers.

Gas turbines are rotary internal combustion engines fueled by natural gas, diesel, or distillate fuel oil and occasionally residual or crude oil. These units range in capacity from 108 MJ/h (40 hp) to over 270 GJ/h (100,000 hp) and may be installed in groups for larger power output. The basic gas

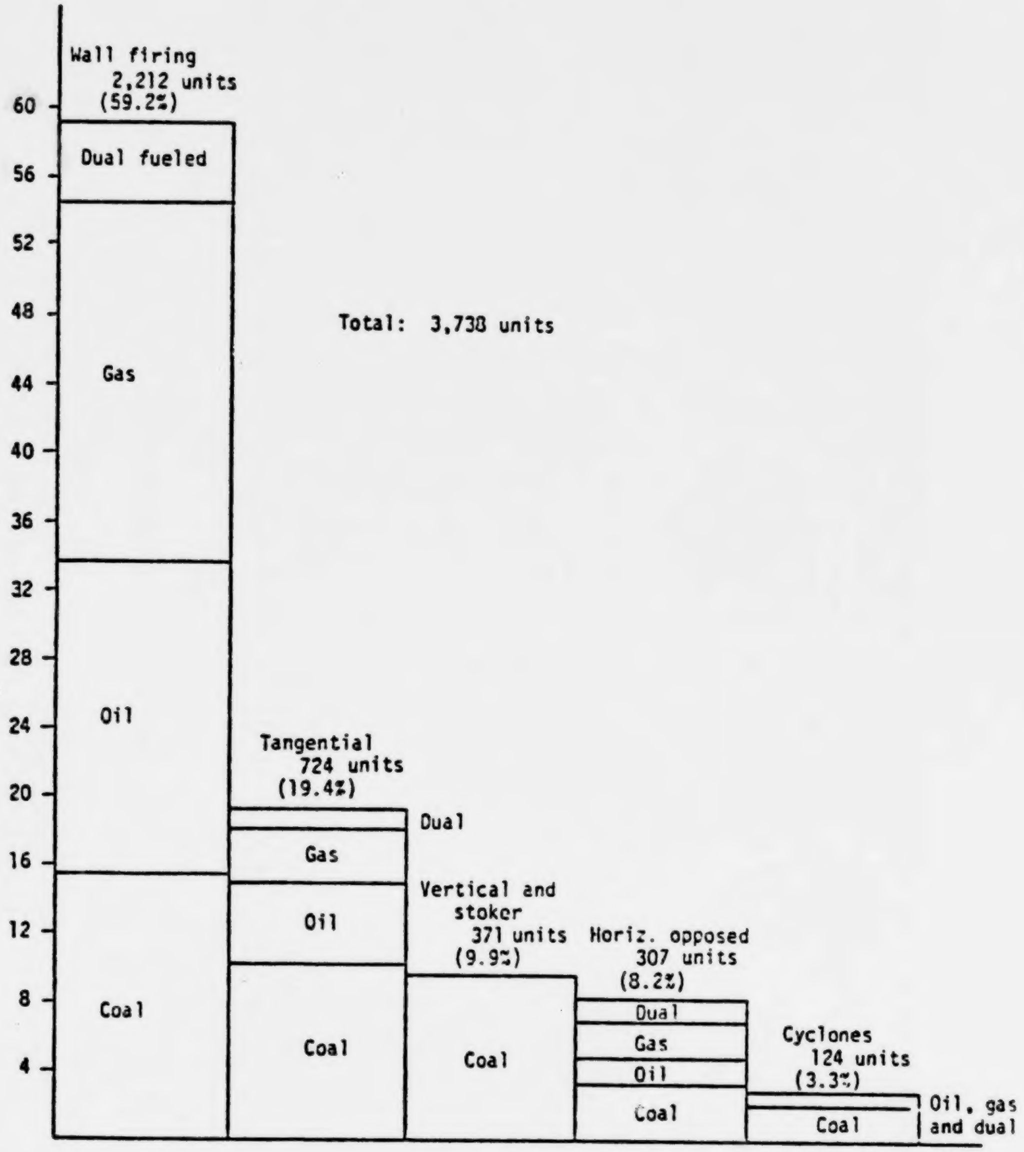

Figure VIC-1. Utility boiler equipment population based on number of installed units.

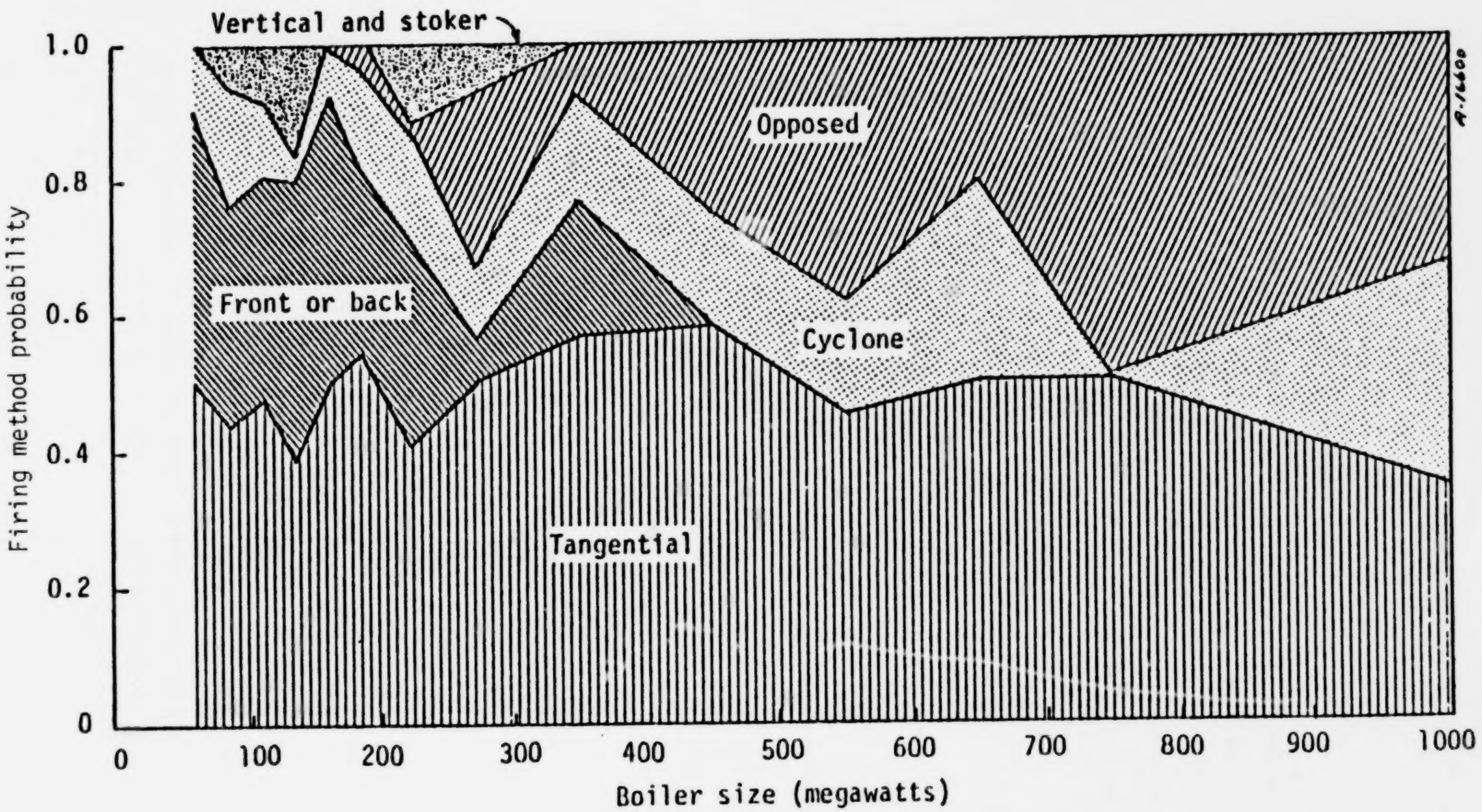

Figure VIC-2. Firing method versus boiler size for pulverized coal-fired (dry bottom) utility boilers.

turbine consists of a compressor, combustion chambers, and a turbine. The compressor delivers pressurized combustion air to the combustors at compression ratios of up to 20 to 1. Injectors introduce fuel into the combustors and the mixture is burned with exit temperatures up to 1,370 K (2,000° F). The hot combustion gases are rapidly quenched by secondary dilution air and then expanded through the turbine, which drives the compressor and provides shaft power.

Regenerative cycle gas turbines also use hot exhaust gases of up to 870 K (1,100° F) to preheat the inlet air between the compressor and the combustor. This makes it possible to recover some of the thermal energy in the exhaust gases and to increase thermal efficiency.

A third type of turbine is the combined-cycle gas turbine. This is a simple-cycle unit that exhausts to a waste heat boiler to recover thermal energy from the exhaust gases. In some cases, this waste heat boiler is also designed to burn additional fuels to supplement steam production.

Gas turbines have been extremely popular in the past decade because of the relatively short construction lead times, low cost, ease and speed of installation, and low physical profile including low buildings, short stacks, little visible emissions, and quiet operation. By far the largest use of gas turbines is for peaking power.

Stationary reciprocating internal combustion engines use two methods to ignite the fuel air mixture in the combustion chamber. In compression ignition engines, air is first compression heated in the cylinder and then diesel fuel is injected into the hot air where ignition is spontaneous. In spark ignition engines the combustion is spark initiated, with the natural gas or gasoline being introduced by injection or premixed with the combustion air in a carbureted system Because reciprocating internal combustion engines characteristically have a low physical profile, they are frequently located in or adjacent to urban centers where power demands are greatest and pollution problems most acute. Seventy-three percent of IC engines are fueled by natural gas, 16 percent by diesel oil, and 11 percent by gasoline. The oil and gas industry is the leading user of stationary IC engines for pipeline and production applications followed by general industrial users, electric power generation, and agriculture.

2. Industrial, Commercial, Residential Combustion Equipment

Combustion equipment for these three sectors can be divided into (a) packaged boilers and (b) warm air furnaces.

Packaged boilers are constructed in water tube, fire tube, cast iron, and shell designs. Each of these designs has a fairly distinct capacity range. These units are fueled primarily by residual and distillate oil, natural gas, and stoker coal. In terms of installed units, packaged boilers far outnumber field-erected boilers. They consume about 91 percent as much fuel as field-erected boilers. Packaged boilers are primarily used for industrial process steam, commercial and residential heating, and hot water supply.

Water tube boilers are essentially the only packaged boiler design available of about 32 GJ/h (30 MBtu/h) and above. Packaged water tube boilers are fueled by residual or distillate oil, natural gas, process gases, stoker and pulverized coal, and waste fuels. Most packaged water tube boilers are burner fired. Only about 15 percent are stoker fired. Fuel oil is used in about 50 percent of the burner fired units and about 40 percent of the units have dual gas and oil capabilities. Units limited to natural gas firing make up the remaining 10 percent. Steam is used as the atomization method for 70 to 80 percent of oil-fuel boilers. Gas burners are usually of the register type. Coal and other solid fuel stokers are used. In the past, pulverized coal has seldom been used in packaged water tube boilers due to capital costs involved. The availability and competitive cost of coal compared to oil are leading to the increased use of pulverized coal in the larger packaged water tube units. Water tube boilers smaller than 108 GJ/h are fired by single burners and use primarily distillate oil or natural gas. The most common atomization method for these units is mechanical pressure atomizing. Coal firing is available only in stoker units.

In fire tube boilers, the products of combustion are directed from the combustion chamber through straight tubes which are submerged in water. Because of the sensitivity to fouling with this design, fire tube boilers normally burn fuel oil and natural gas. The firing is by single burner. Rotary, mechanical, or air atomization is used for oil firing; power burners are predominantly used for natural gas firing. Fire tube boilers are used for commercial and domestic space heating with larger units being used for industrial process steam.

Cast iron boilers are available in capacities up to 14 GJ/h (13.5 MBtu/h). They operate almost exclusively on distillate oil and natural gas fuels. They are designed to supply low pressure steam or hot water and are used primarily for air or water heating systems. The primary advantage of cast iron boilers for heating is that they require a very low level of maintenance and have a high reliability and long lifetime.

Other package boilers used for residential and commercial heating or hot water include shell boilers and residential steam and hot water units.

The large majority of warm air furnaces (about 60 percent of new units) are forced air central furnaces with capacities up to about 317 MJ/h (approximately 300,000 Btu/h). These heaters are operated either by gravity or by a pressure blower (forced air system) for air discharge and return. Central gravity-operated furnaces rarely exceed 159 MJ/h (150,000 Btu/h). The furnace in these central heaters is enclosed in a rectangular steel casing and fuel is burned in the primary combustion space of a metal-wall heat exchanger. Heat exchangers in these warm-air furnaces have a single combustion chamber, which is usually cylindrical or divided into a series of individual sections. Cylindrical combustion chambers are normally used with a single-port oil-fired burner, and the sectional type is used with multiple gas-fired burners. Combustion products pass through secondary flue gas passages of the heat exchanger and exit through a flue to the atmosphere.

D. DISCUSSION OF SOURCE CHARACTERIZATION

The present study seeks to identify those organizations performing various elements of combustion pollution assessment and to compare these elements in order to determine the degree of overlap or areas that are not being adequately addressed. Such a comparison, in order to be accurate, must include at least the following information:

- fuel type,
- burner type,
- sampling point(s),
- pollutants identified, and
- analytical methods used.

These data should be unambiguously specified. One problem encountered early in the present survey was the use of various methods of fuel-burner type classification which made direct comparison of programs, e.g., through work plans, difficult. This difficulty may be illustrated by consideration of the work plans for the current contracts of TRW (EPA Contract No. 68-02-2197) and the Aerotherm Division of the Acurex Corporation (EPA Contract No. 68-02-2160).

The TRW system is based on a system used by GCA, which is based on the NEDS system. The GCA classification code for coal-fired utility boilers is shown in Table VID-1. Table VID-2 shows the classification system for oil-fired electric utility boilers for 1972 and Table VID-3 for gas-fired electric utility boilers. A similar classification code exists for industrial, commercial, institutional, and residential burner systems.

The classification method shown in the cited tables is relatively precise. Furthermore, the numerical code facilitates storage and retrieval from a computer data base, which is essential for detailed comparison of a large number of projects.

However, GCA reduced the detail of its boiler classifications for the purpose of emission tables in its report, as shown in Table VID-4, by dropping the last two digits of the codes shown in Table VID-1 and one digit from those in Tables VID-2 and 3. For coal type fuels this simplification eliminates all consideration of single-wall fired boilers, opposed-wall fired boilers, and tangentially fired boilers from the coal type fuels category. It also eliminates consideration or distinguishing of wall-fired burners for petroleum and gas fuels. Yet all three of these important subcategories produce varying emissions.

A similar code is being used by TRW in its work plans and reports, as shown in Table VID-5. The same difficulty is encountered here.

The categorization used by Aerotherm and by Exxon will now be considered. Figure VID-1 demonstrates the system for utility boilers. As may be seen, this categorization is relatively simple. Although the entire fuel-burner system to be considered can be taken in at a glance for any given array of the category shown, the system has no subcategories for relative size. This system, as presently being used, has not yet been reduced to a numerical coding system, although one similar to the TRW scheme could readily be devised.

For coal-fired utility boilers in comparison, problems are obvious. As shown, for example, in the TRW-GCA system, the first major subdivision of

TABLE VID-1. CLASSIFICATION CODES FOR COAL-FIRED ELECTRIC UTILITY BOILERS

1.1.10.0.0	Coal
1.1.10.1.0.0.0	Pulverized dry
1.1.10.1.1.0.0	Tangential
1.1.10.1.1.0.1	With fly ash reinjection
1.1.10.1.1.0.2	Without fly ash reinjection
1.1.10.1.1.1.2	>5000 10^6 Btu/h
1.1.10.1.1.2.2	1500-5000
1.1.10.1.1.3.2	500-1500
1.1.10.1.1.4.2	<500
1.1.10.1.3.0.0	Front
1.1.10.1.3.0.1	With fly ash reinjection
1.1.10.1.3.1.1	>5000 10^6 Btu/h
1.1.10.1.3.2.1	1500-5000
1.1.10.1.3.3.1	500-1500
1.1.10.1.3.4.1	<500
1.1.10.1.3.0.2	Without fly ash reinjection
1.1.10.1.3.1.2	>5000 10^6 Btu/h
1.1.10.1.3.2.2	1500-5000
1.1.10.1.3.3.2	500-1500
1.1.10.1.3.4.2	<500
1.1.10.1.4.0.0	Opposed
1.1.10.1.4.0.1	With fly ash reinjection
1.1.10.1.4.1.1	>5000 10^6 Btu/h
1.1.10.1.4.2.1	1500-5000
1.1.10.1.4.3.1	500-1500
1.1.10.1.4.4.1	<500
1.1.10.1.4.0.2	Without fly ash reinjection
1.1.10.1.4.1.2	>5000 10^6 Btu/h
1.1.10.1.4.2.2	1500-5000
1.1.10.1.4.3.2	500-1500
1.1.10.1.4.4.2	<500
1.1.10.2.0.0.0	Pulverized wet
1.1.10.2.1.0.0	Tangential
1.1.10.2.1.0.1	With fly ash reinjection
1.1.10.2.1.1.1	>5000 10^6 Btu/h
1.1.10.2.1.2.1	1500-5000
1.1.10.2.1.3.1	500-1500
1.1.10.2.1.4.1	<500

TABLE VID-1. (con.)

1.1.10.2.1.0.2	Without fly ash reinjection
1.1.10.2.1.1.2	>5000 10^6 Btu/h
1.1.10.2.1.2.2	1500-5000
1.1.10.2.1.3.2	500-1500
1.1.10.2.1.4.2	<500
1.1.10.2.3.0.0	Front
1.1.10.2.3.0.1	With fly ash reinjection
1.1.10.2.3.0.2	Without fly ash reinjection
1.1.10.2.3.1.2	>5000 10^6 Btu/h
1.1.10.2.3.2.2	1500-5000
1.1.10.2.3.3.2	500-1500
1.1.10.2.3.4.2	<500
1.1.10.2.4.0.0	Opposed
1.1.10.2.4.0.1	With fly ash reinjection
1.1.10.2.4.1.1	>5000 10^6 Btu/h
1.1.10.2.4.2.1	1500-5000
1.1.10.2.4.3.1	500-1500
1.1.10.2.4.4.1	<500
1.1.10.2.4.0.2	Without fly ash reinjection
1.1.10.2.4.1.2	>5000 10^6 Btu/h
1.1.10.2.4.2.2	1500-5000
1.1.10.2.4.3.2	500-1500
1.1.10.2.4.4.2	<500
1.1.10.3.0.0.0	Cyclone
1.1.10.3.0.0.1	With fly ash reinjection
1.1.10.3.0.1.1	>5000 10^6 Btu/h
1.1.10.3.0.2.1	1500-5000
1.1.10.3.0.3.1	500-1500
1.1.10.3.0.4.1	<500
1.1.10.3.0.0.2	Without fly ash reinjection
1.1.10.3.0.1.2	>5000 10^6 Btu/h
1.1.10.3.0.2.2	1500-5000
1.1.10.3.0.3.2	500-1500
1.1.10.3.0.4.2	<500
1.1.10.4.0.0.0	All stokers
1.1.10.4.0.1.0	>5000 10^6 Btu/h
1.1.10.4.0.2.0	1500-5000
1.1.10.4.0.3.0	500-1500
1.1.10.4.0.4.0	<500
1.x.xx.x.x.x.x	Other

TABLE VID-2. CLASSIFICATION CODES FOR OIL-FIRED ELECTRIC UTILITY BOILERS

1.1.20.0.0.0	Petroleum
1.1.20.0.1.0	Tangential
1.1.20.0.1.1	>5000 10^6 Btu/h
1.1.20.0.1.2	1500-5000
1.1.20.0.1.3	500-1500
1.1.20.0.1.4	<500
1.1.20.0.2.0	All others
1.1.20.0.3.0	Front or back
1.1.20.0.3.1	>5000 10^6 Btu/h
1.1.20.0.3.2	500-5000
1.1.20.0.3.3	500-1500
1.1.20.0.3.4	<500
1.1.20.0.4.0	Opposed
1.1.20.0.4.1	>5000 10^6 Btu/h
1.1.20.0.4.2	1500-5000
1.1.20.0.4.3	500-1500
1.1.20.0.4.4	<500
1.1.20.0.9.0	Other
1.1.20.0.9.1	>5000 10^6 Btu/h
1.1.20.0.9.2	1500-5000
1.1.20.0.9.3	500-1500
1.1.20.0.9.4	<500

TABLE VID-3. CLASSIFICATION CODES FOR GAS-FIRED ELECTRIC UTILITY BOILERS

1.1.30.0.0.0	Gas
1.1.30.0.1.0	Tangential
1.1.30.0.1.1	>5000 10^6 Btu/h
1.1.30.0.1.2	1500-5000
1.1.30.0.1.3	500-1500
1.1.30.0.1.4	<500
1.1.30.0.2.0	All others
1.1.30.0.3.0	Front or back
1.1.30.0.3.1	>5000 10^6 Btu/h
1.1.30.0.3.2	500-5000
1.1.30.0.3.3	500-1500
1.1.30.0.3.4	<500
1.1.30.0.4.0	Opposed
1.1.30.0.4.1	>5000 10^6 Btu/h
1.1.30.0.4.2	1500-5000
1.1.30.0.4.3	500-1500
1.1.30.0.4.4	<500
1.1.30.0.9.0	Other
1.1.30.0.9.1	>5000 10^6 Btu/h
1.1.30.0.9.2	1500-5000
1.1.30.0.9.3	500-1500
1.1.30.0.9.4	<500

TABLE VID-4. CONDENSED CLASSIFICATION CODE FOR ELECTRIC UTILITY SOURCES

Classification system number	Combustion system category
1.0.00.0.0	Electric generation
1.1.00.0.0	External combustion
1.1.10.0.0	Coal
1.1.11.0.0	Bituminous
1.1.11.1.0	Pulverized dry
1.1.11.2.0	Pulverized wet
1.1.11.3.0	Cyclone
1.1.11.4.0	All stokers
1.1.12.0.0	Anthracite
1.1.12.1.0	Pulverized dry
1.1.12.2.0	Pulverized wet
1.1.12.3.0	Cyclone
1.1.12.4.0	All stokers
1.1.13.0.0	Lignite
1.1.13.1.0	Pulverized dry
1.1.13.2.0	Pulverized wet
1.1.13.3.0	Cyclone
1.1.13.4.0	All stokers
1.1.20.0.0	Petroleum
1.1.21.0.0	Residual oil
1.1.21.0.1	Tangential firing
1.1.21.0.2	All other
1.1.22.0.0	Distillate oil
1.1.22.0.1	Tangential firing
1.1.22.0.2	All other
1.1.30.0.0	Gas
1.1.30.0.1	Tangential firing
1.1.30.0.2	All other
1.1.40.1.1	Refuse
1.2.00.0.0	Internal combustion
1.3.00.0.0	Turbine
1.3.20.0.0	Petroleum
1.3.30.0.0	Gas
1.4.00.0.0	Reciprocating
1.4.20.0.0	Petroleum
1.4.30.0.0	Gas

TABLE VID-5. CLASSIFICATION CODES USED BY TRW

No.	I.D. code	Source type
GROUP I A		
3	4.1.22.0.0	Residential ext. comb. dist. oil
4	4.1.30.0.0	Residential ext. comb. gas
7	3.1.21.0.2	Comm./instit. ext. comb. resid. oil, other
8	3.1.21.0.1	Comm./instit. ext. comb. resid. oil, tang
9	3.2.22.0.0	Comm./instit. int. comb. dist. oil
10	3.1.22.0.1	Comm./instit. ext. comb. dist. oil, tang
11	3.1.22.0.2	Comm./instit. ext. comb. dist. oil, other
GROUP I B		
1	3.1.30.0.2	Comm./instit. ext. comb. gas, other
2	3.2.30.0.0	Comm./instit. int. comb. gas
3	3.1.30.0.1	Comm./instit. ext. comb. gas, tang
4	3.1.12.4.0	Comm./instit. ext. comb. anthracite, stoker
5	3.1.11.4.0	Comm./instit. ext. comb. bituminous, stoker
6	3.1.11.1.0	Comm./instit. ext. comb. bituminous pulv., dry
7	3.1.11.2.0	Comm./instit. ext. comb. bituminous pulv., wet
8	2.1.21.0.2	Industrial ext. comb. resid. oil, other
9	2.1.21.0.1	Industrial ext. comb. resid. oil, tang
GROUP I C		
1	2.1.11.4.0	Industrial ext. comb. bituminous, stoker
2	2.1.11.2.0	Industrial ext. comb. bituminous, pulv., wet
3	2.1.11.3.0	Industrial ext. comb. bituminous, cyclone
4	2.1.30.0.2	Industrial ext. comb. gas, other
5	2.4.30.0.0	Industrial int. comb. gas, recipr. eng.
6	2.3.30.0.0	Industrial int. comb. gas, turbine
7	2.1.30.0.1	Industrial ext. comb. gas, tang
GROUP II A		
1	1.1.11.2.0	Elect. gen. ext. comb. bituminous, pulv., wet
2	1.1.11.3.0	Elect. gen. ext. comb. bituminous, cyclone
3	1.1.11.4.0	Elect. gen. ext. comb. bituminous, stoker
4	1.1.21.0.2	Elect. gen. ext. comb. resid. oil, other
5	1.1.21.0.1	Elect. gen. ext. comb. resid. oil, tang
6	1.3.22.0.0	Elect. gen. int. comb. dist. oil, turbine
7	1.4.22.0.0	Elect. gen. int. comb. dist. oil, recipr. eng.
8	1.3.30.0.0	Elect. gen. int. comb. gas, turbine
9	1.4.30.0.0	Elect gen. int. comb. gas, recipr. eng.
10	1.1.30.0.2	Elect. gen. ext. comb. gas, other
11	1.1.30.0.1	Elect. gen. ext. comb. gas, tang

TABLE VID-5. (con.)

No.	I.D. code	Source type
GROUP II B		
1	1.1.22.0.2	Elect. gen. ext. comb. dist. oil, other
2	1.1.22.0.1	Elect. gen. ext. comb. dist. oil, tang
3	1.1.12.4.0	Elect. gen. ext. comb. anthracite, stoker
4	1.1.12.1.0	Elect. gen. ext. comb. anthracite, pulv., dry
5	1.1.13.1.0	Elect. gen. ext. comb. lignite, pulv., dry
6	1.1.13.2.0	Elect. gen. ext. comb. lignite, pulv., wet
7	1.1.13.3.0	Elect. gen. ext. comb. lignite, cyclone
8	1.1.13.4.0	Elect. gen. ext. comb. lignite, stoker
GROUP II C		
1	1.1.40.0.0	Elect. gen. ext. comb., refuse
2	2.4.22.0.0	Industrial int. comb., dist. oil, recip.
3	2.1.22.0.2	Industrial ext. comb., dist. oil, other
4	2.3.22.0.0	Industrial int. comb., dist. oil, turbine
5	2.1.22.0.1	Industrial ext. comb., dist. oil, tang
6	2.1.40.0.0	Industrial ext. comb., refuse
7	2.1.12.4.0	Industrial ext. comb., anthracite, stoker
8	2.1.13.4.0	Industrial ext. comb., lignite, stoker

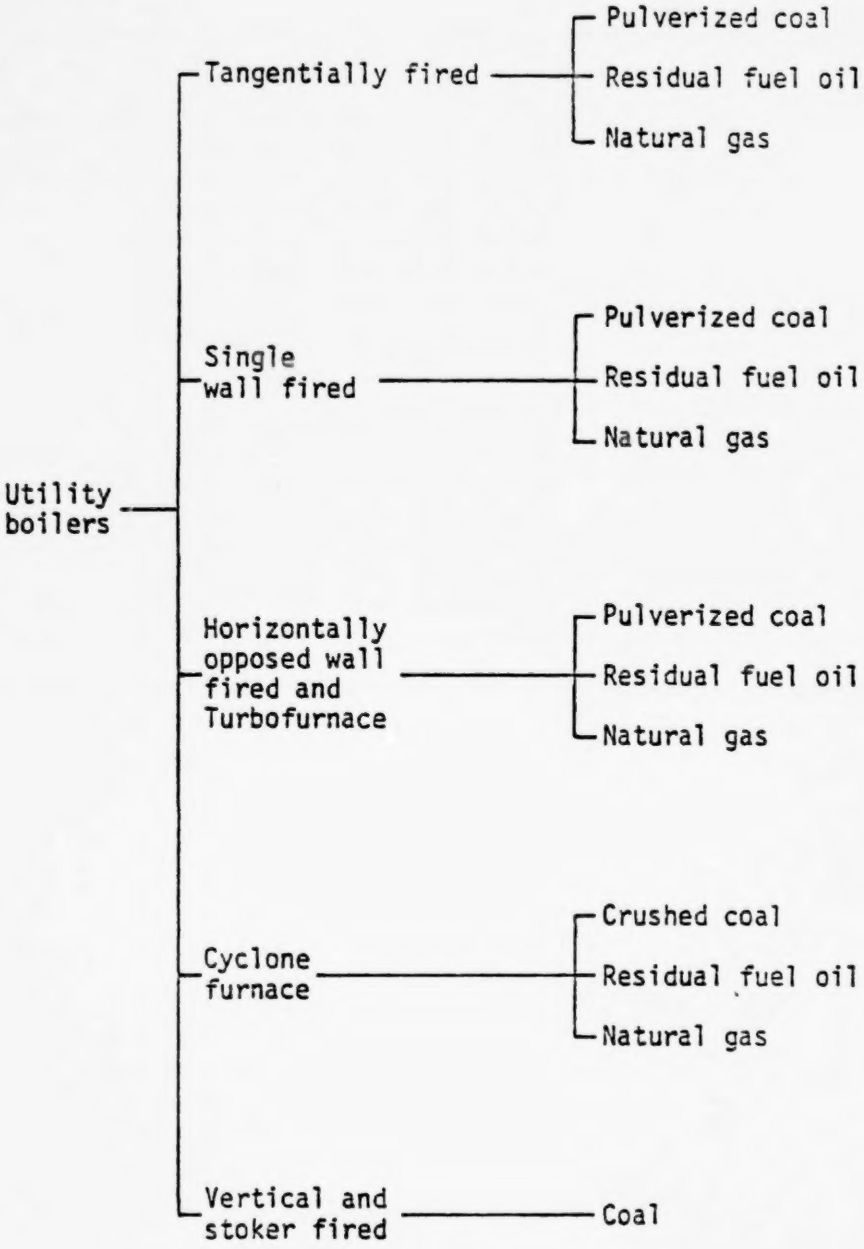
Utility boilers
Tangentially fired
Pulverized coal
Residual fuel oil
Natural gas
Single wall fired
Pulverized coal
Residual fuel oil
Natural gas
Horizontally opposed wall fired and Turbofurnace
Pulverized coal
Residual fuel oil
Natural gas
Cyclone furnace
Crushed coal
Residual fuel oil
Natural gas
Vertical and stoker fired
Coal

Figure VID-1. Utility boiler equipment categories used by Aerotherm.

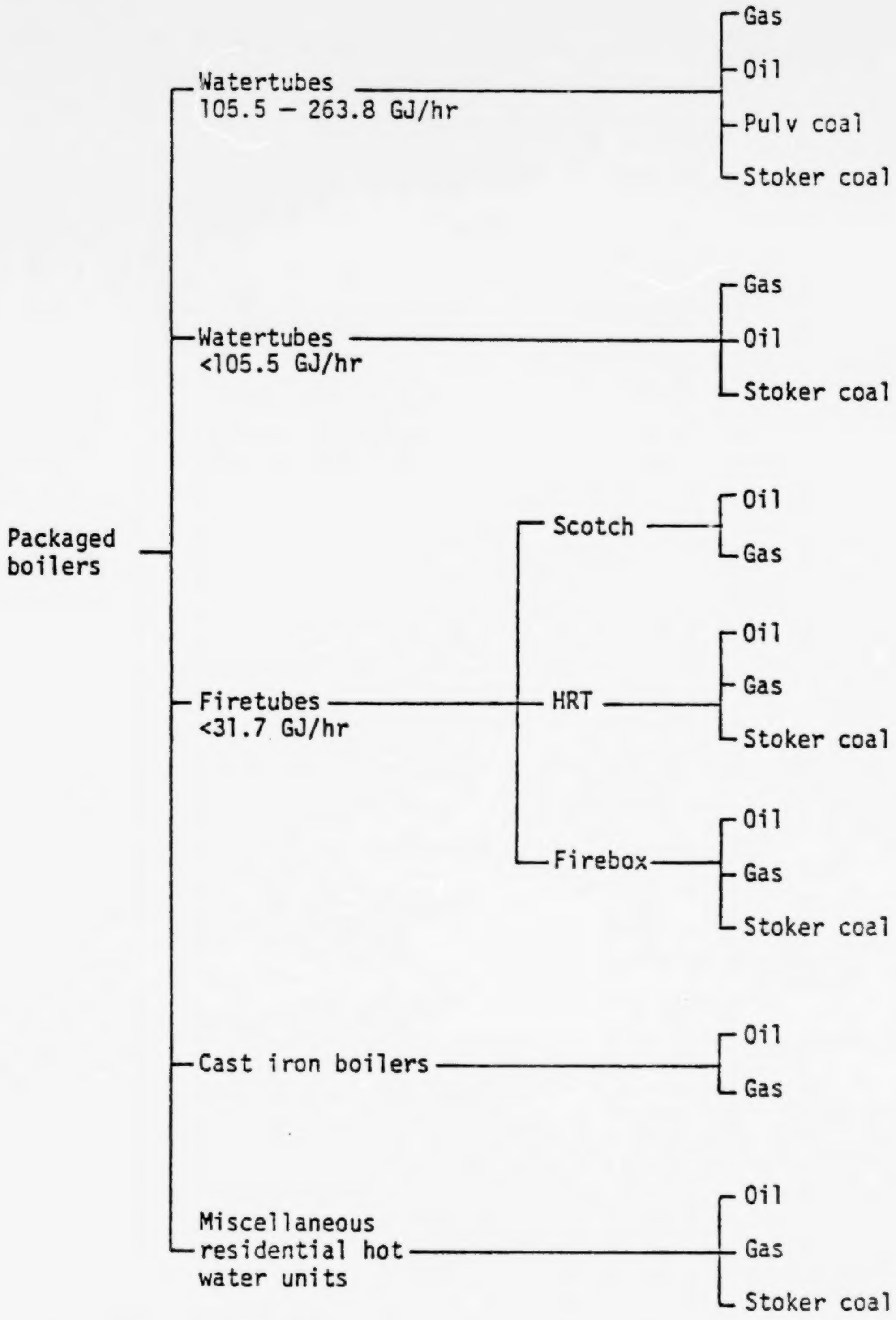
Packaged boilers
Watertubes 105.5 – 263.8 GJ/hr
Gas
Oil
Pulv coal
Stoker coal
Watertubes <105.5 GJ/hr
Gas
Oil
Stoker coal
Firetubes <31.7 GJ/hr
Scotch
Oil
Gas
HRT
Oil
Gas
Stoker coal
Firebox
Oil
Gas
Stoker coal
Cast iron boilers
Oil
Gas
Miscellaneous residential hot water units
Oil
Gas
Stoker coal

Figure VID-2. Packaged boiler equipment categories used by Aerotherm.

TABLE VID-6. GCA INDUSTRIAL SOURCE EXTERNAL COMBUSTION CATEGORIES

2.0.00.0.0	Industrial
2.1.00.0.0	External Combustion
2.1.10.0.0	Coal
2.1.11.0.0	Bituminous
2.1.11.1.0	Pulverized dry
2.1.11.2.0	Pulverized wet
2.1.11.3.0	Cyclone
2.1.11.4.0	All stokers
2.1.11.5.0	Overfeed stokers
2.1.11.6.0	Spreader stokers
2.1.11.7.0	Underfeed stokers
2.1.12.0.0	Anthracite
2.1.12.1.0	Pulverized dry
2.1.12.2.0	Pulverized wet
2.1.12.4.0	All stokers
2.1.13.0.0	Lignite
2.1.13.1.0	Pulverized dry
2.1.13.2.0	Pulverized wet
2.1.13.4.0	All stokers
2.1.13.5.0	Overfeed stokers
2.1.13.6.0	Spreader stokers
2.1.13.7.0	Underfeed stokers
2.1.20.0.0	Petroleum
2.1.21.0.0	Residual oil
2.1.21.0.1	Tangential firing
2.1.21.0.2	All other
2.1.22.0.0	Distillate oil
2.1.22.0.1	Tangential firing
2.1.22.0.2	All other
2.1.30.0.0	Gas
2.1.30.0.1	Tangential firing
2.1.30.0.2	All other
2.1.41.0.0	Bagasse
2.1.42.0.0	Wood/bark

coal-fired boilers is by pulverized dry and pulverized wet bottom furnaces. In the Aerotherm-Exxon system, pulverized dry and pulverized wet bottom furnaces are a subcategory under the major breakdown of tangentially, single-wall, and opposed-wall fired burner designs.

Similar and perhaps even more difficult problems in comparing the boiler types being studied under different programs may be seen by examining the breakdowns for industrial categories. These are readily apparent from comparison of Figure VID-2 with the GCA breakdown for industrial classes as shown in Table VID-6.

From the above discussion it is clear that IERL/RTP needs to develop a standardized coding system for all sectors (utilities, industrial, commercial/institutional, and residential). Such a system is particularly needed for management and control purposes, including use in such documents as proposals, work plans, and project reports.

E. EMISSIONS MEASUREMENTS

This section will briefly survey some of the significant projects in which measurements are being made of emissions from conventional combustion sources. A more complete listing of recent and current project activity can be found in Appendix D. For convenience, the survey is grouped to consider projects in which measurements are being made on a variety of source types and those in which measurements are being made on a single source type.

1. Multisource Programs

Three large projects sponsored by EPA in which emissions from a variety of conventional sources are being determined are:

- TRW--Emissions Assessment of Conventional Combustion Systems, EPA Contract No. 68-02-2197
- Acurex/Aerotherm--Environmental Assessment and Systems Analysis of Stationary Source Combustion Control Technology, EPA Contract No. 68-02-2160.
- Exxon--The Effect of Combustion Modification on Pollutants and Equipment Performance of Power Generation Equipment, EPA Contract No. 68-02-1415.

There are numerous similarities among these three programs. For example, they are all making emissions measurements on similar source types, all three current programs are for approximately 3 years duration, and all are significantly funded (Exxon $1.4 million, Aerotherm $2.7 million, and TRW $3.8 million).

However, there are significant differences. These include:

a. TRW and Aerotherm are making significant literature studies assessing the adequacy of existing data. Exxon is not, although they are well aware of literature data from past studies dating from the late 1960's.

b. Both TRW and Aerotherm are considering all of the sectors (utilities, industrial, commercial/institutional, and residential) while the Exxon study is limited to utility boilers.

c. All are considering at least some units using coal, oil, or gas. Exxon has, in addition, two units that are using dual fuels (coal-gas and coal-oil) both of which are tangentially fired units. These may be important fuel types in the future.

d. The Exxon program is limited to 14 boilers. These are single-wall fired boiler (3), horizontally opposed (4), tangential (4), and turbines (3). As we have seen, TRW plans to assess over 50 categories at 170 sites. The number and definition of sites that Aerotherm will assess are not known as yet but are presumed to be numerous.

e. Both TRW and Aerotherm are examining air, water, and solid waste streams while Exxon is limited to air emissions (flue gas).

As has been discussed previously, in order to compare programs it is vital to know the pollutants identified, the sampling point, and the analytical methods used. Table VIE-1 gives a typical measurement program array for the Exxon project. The Aerotherm and TRW plans are similar to this, but there are some differences. For example, Aerotherm and TRW are using atomic absorption methods for trace elements in place of the neutron activation analysis used by Exxon. Exxon is the only one of the three that has clearly specified its sampling points to date. It should also be noted that Exxon has only been

TABLE VIE-1. EXXON'S ANALYTICAL INSTRUMENTS

Pollutant	Instrument
NO	Nondispersive IR
NO_2	Nondispersive UV
NO_x	Chemiluminescence
CO	Nondispersive IE
SO_2	Nondispersive IR
Trace elements	Neutron activation analysis
Organics	Spark source mass spec.
SO_4	Level 1
NO_3	Level 1
HCl	Level 1
HCN	Level 1
Sampling point	Between economizer and air heater
Coal analyses	Coal from feeder
Particulates	SASS Train

analyzing for this array of pollutants since early 1977. But its history of measurement of criteria pollutants covers a span of almost 10 years.

In addition to baseline measurements of the pollutants indicated, Exxon and Aerotherm have a counterpart heavy emphasis on the effect of various forms of NO_x control methods on pollutant emissions.

Furthermore, the present Exxon program concerns itself with the effects of NO_x control methods on boiler corrosion problems.

Table D2 in Appendix D lists research projects in which emissions measurements from many types of sources are being made.

2. Utility Sources

EPA is sponsoring a 4-year study by TVA to characterize and quantify air and liquid waste emissions from full-scale operating coal-fired utility boilers, including coal pile drainage, ash pond effluent, cooling water, and ash pond leachate to ground water. An ash monitoring program has been designed and is being evaluated for effectiveness. Also under EPA sponsorship, Brookhaven National Laboratory has studied the SO_2 and SO_4 content of power plant stack emissions.

Another area of recent research interest has been the extent of high molecular weight organic compounds in power plant emissions. EPA has recently sponsored two projects in this area, both carried out by Southern Research Institute. ERDA has also sponsored a similar study by Ames Laboratory.

Another ERDA-sponsored project has been carried out by the University of New Hampshire to investigate the mechanisms of fly ash formation in coal-fired utility boilers.

The Environmental Division of the Lawrence Livermore Laboratory of the University of California is conducting a continuing multisource emissions measurement program entitled "Trace Element Emissions from Western U.S. Coal-Fired Power Plants" (ERDA). Funding is approximately $300,000 a year. Single-wall, opposed-wall, and tangentially fired units are being studied.

Emissions are being sampled simultaneously both in the stack and the plume. They contend that they are one of the few organizations fully realizing the importance of simultaneous stack and plume sampling. Plume samples are being collected by airplane at various intervals for a distance of 40 miles from the stack to determine transport and fate effects.

The effects of the use of venturi scrubbers and electrostatic precipitators are also being studied. Although the major effort is on trace elements, emission rates for high molecular weight organics, radioactive nuclides, and sulfur- and nitrogen-containing species are also being determined.

The major analytical methods being used are shown in Table VIE-2. These methods are analogous to those of EPA Level II.

During the course of the project several conclusions have been reached that may be quite important to CCEA. These are:

a. The particle size distributions of trace elements and stack emissions are significantly different in different power plants and also for the different emission control systems at the same power plants.

b. Generalizations are not valid in determining the potential inhalation effects from coal-fired power plants. Each particular set of stack emissions must be examined.

c. Comparison of pulmonary deposition of several toxic particulate species from the two devices suggests that the use of venturi scrubbers, as opposed to electrostatic precipitators, for particulate emission control may result in increased potential for pulmonary exposure.

Future work is planned at a utility that has available a hot side electrostatic precipitator and a Wellman-Lord unit for control of SO_x. The sulfites used in the Wellman-Lord process are known to have mutagenic properties. However, they have been considered to be short-lived because they are easily oxidized. Additionally, it is hypothesized that the trace elements present in the gas stream may stabilize the sulfites. The project will seek to confirm this.

These research projects on utility boiler emissions are listed in Table D3 of Appendix D.

3. Industrial Boilers

Project activity in this area has primarily been supported by EPA. Table D4 in Appendix D lists some of the more significant projects in this category.

Over the period 9/74-3/77, KVB carried out, under EPA sponsorship, significant pollutant studies on industrial boilers. The program was titled

TABLE VIE-2. LAWRENCE LIVERMORE LABORATORY POLLUTANTS AND ANALYTICAL METHODS

Trace element analyses	Instrumental neutron activation analysis (INAA).
	Atomic absorption spectroscopy (AAS).
	Cold vapor atomic absorption spectroscopy (for Hg vapor).
	X-ray fluorescence analysis (XRF).
	X-ray microprobe.
Particle sizing	Scanning electron microscopy (SEM).
	Coulter analyses.
	Centrifugal sedimentation.
Polynuclear aromatic	Gas chromatography-mass spectrometry (GC/MS).
Sulfur speciation	Electron spectroscopy for chemical analysis (ESCA).

"Field Testing: Application of Combustion Modifications to Control Pollutant Emissions" (EPA 68-02-1074).

Forty-seven industrial boilers ranging in size from 3 MW to 147 MW were tested. The fuels evaluated were coal, oil, and natural gas.

Although the program also addressed combustion modifications, extensive baseline data were obtained. The combustion modifications will be discussed in Section VII of this report. The pollutants measured and the instrumentation used are shown in Table VIE-3. The data collected represent probably the most extensive air emissions characterization of industrial boilers to date.

The American Boiler Manufacturers Association is sponsoring an interesting program on stoker-fired industrial boilers. The program will be carried out in cooperation with ERDA and EPA with input from other interested technical groups such as the National Coal Association. KVB will be the subcontractor for site monitoring and measurements. This is a new program and only limited details are available. It is planned to assess six stoker-fired industrial boilers with a range of steam flow from 75,000 to 250,000 lb/h. Various types of coal will be selected to be studied including lignite and anthracite. Some of the objectives of the program are:

- To advance boiler and stoker technology.
- To refine applications of existing pollution control equipment.
- To contribute to the design of new and improved air pollution control equipment.
- To facilitate reasonable national emissions standards.
- To facilitate planning for coal supply contractors.
- To promote the increased utilization of stoker coal-fired boilers by U.S. industry by meeting environmental requirements.

The test program is an industry first in that the American Boiler Manufacturers Association and associated industries and Federal agencies have agreed upon a combined effort to encourage design and application of stoker coal-fired industrial boilers.

Another program to assess stoker-fired boilers has recently been started by Batelle under EPA Contract No. 68-02-2627. The project title is "Evaluation of Emissions and Control Technology for Industrial Stoker Boilers." The

TABLE VIE-3. KVB EMISSIONS MEASURED AND INSTRUMENTATION

Emission	Symbol	Measurement method	Equipment manufacturer
Nitric oxide	NO	Chemiluminescent	Thermo Electron
Oxides of nitrogen	NO_x	Chemiluminescent	Thermo Electron
Carbon monoxide	CO	Spectrometer (NDIR)	Beckman
Carbon dioxide	CO_2	Spectrometer (NDIR)	Beckman
Oxygen	O_2	Polarographic	Teledyne
Hydrocarbons	HC	Flame ionization	Beckman
Sulfur dioxide and trioxide	SO_2, SO_3	Absorption/ titration	KVB Equipment Co.
Total particulate matter	--	EPA Std Method 5	Joy Mfg Co.
Particulate size	--	Cascade impactor	Monsanto
Smoke spot	--	Reflection	Research Appliance
Opacity	--	EPA Std Method 9	--
Trace species and organics	TS & O	Modified EPA Method 5	Train design by Midwest Research Institute

units to be studied are a small 20-hp underfeed stoker boiler and a commercially available 600-hp spreader stoker boiler. The major thrust of the program is to evaluate the effect on emissions of burning various types of coal.

The coals to be studied in detail include untreated coals; physically treated (reconstituted) coals; and processed (chemically treated or solvent refined) coals. This is the only study we have seen in which these three types of coal are being studied in single firing-type units.

Measurements are projected for both the flue gas and ash. All Level 1 pollutants will be assessed by Level 1 methods. The program is designed to provide a complete profile of the air pollution potential from this type of firing equipment.

Another study of stoker-fired industrial boilers entitled "Western Coal Use in Industrial Boilers," EPA Contract No. 68-02-1863, was carried out by KVB.

The purpose of this study was to determine the feasibility of substituting western subbituminous coal for eastern bituminous coal as a means of reducing the SO_x emissions from this class of boiler, and to demonstrate the feasibility of greatly expanded western coal utilization as a means of reducing the use of oil and gas. Test sites included nine stoker-fired boilers and one single-wall pulverized-coal-fired boiler. The boilers ranged in size from 10,000 to 250,000 lb/h of steam. Each boiler was tested on both eastern and western coals for a period of time sufficient to completely characterize their individual emissions and operational characteristics. The effect of fuel switching on SO_x, NO_x, CO, particulates, and unburned hydrocarbon emissions was assessed. The western coals were found to be superior to eastern coals in terms of lower emissions, but boiler efficiency with western coals was found to be lower.

KVB recently completed a study called "Application of Combustion Modifications to Industrial Combustion Equipment" (EPA Contract No. 68-02-2144). In the course of the work, extensive baseline data were obtained as well as measurements on the effect of combustion modification. The control results are discussed in Section VII.

Twenty-two widely varying burners were tested in sixteen facilities. The combustion devices tested and the fuels burned in each device are shown in

Table VIE-4. The pollutants measured for these combustion sites and the measurement method are shown in Table VIE-5.

The Pennsylvania State University has proposed an interesting study on industrial boilers to ERDA and it is expected that the program will be funded shortly. The work will be carried out using a small laboratory furnace for experimental work, a large laboratory furnace (1.5 x 10^6 Btu/h), and power plant boilers located at the university. One feature is the study of unusual fuel systems including oil/water emulsions, oil/coal dispersions, and the products of coal liquefaction. The fuel-burner combinations are shown in Table VIE-6. Products of combustion to be measured include CO, CO_2, O_2, NO_x, SO_x, hydrocarbons, and CH_4. Measurements will be made both in the combustion chamber and at the stack.

The Pittsburgh Energy Research Center (ERDA) has significant programs on a broad area of coal research. There are two active programs on coal combustion as well as programs on coal liquefaction and gasification.

One primary objective of their work in coal combustion is the development of equipment and procedures for the clean burning of coal-oil slurries for use in electric power generation. Just this year a highly instrumented coal slurry combustion test facility with a 700 hp water tube package boiler typical of medium to large size oil-fired industrial boilers is being brought on stream. Detailed evaluations of slurry combustion characteristics and pollutant emissions are being made. Also bottom ash removal and pollutant control techniques will be developed.

A second program is to develop techniques for burning unusual fuels. These fuels include char produced from coal conversion, solvent refined coal, synthane char, and agricultural wastes.

Preliminary work has indicated that existing boilers designed to burn oil or gas can be converted to burn coal/oil slurries at relatively low cost as compared to the higher cost and longer time for conversion to firing coal alone.

The center has an expansive analytical instrumentation capability.

4. Commercial, Institutional, and Residential Sources

Although these categories of sources collectively consume much less energy than utility and industrial sources, there is still a potential for significant adverse health impacts because of the proximity of these sources

TABLE VIE-4. KVB INDUSTRIAL COMBUSTION TEST UNITS
SELECTED AND SUMMARY OF RESULTS OBTAINED

Device type	Fuel	Combustion modification[1]
Natural draft process heater	Ref. gas	4/32 BOOS
Natural draft process heater	Ref. gas	Air register adjust
Natural draft process heater.	Ref. gas	High load, low O_2
Natural draft process heater	Ref. gas	2/16 BOOS
Natural draft process heater	Ref. gas	Air register adjust
Forced draft heater, air preheat	Ref. gas	Baseline lowest O_2
	No. 6 oil	Low O_2 no effect
Forced draft heater	Ref. gas	Low O_2
	No. 6 oil	Low O_2
Clay tunnel kiln	Nat. gas	Low O_2
Rotary cement kiln (dry process)	Nat. gas NG + coke	Fuel switch, Gas to coke
Rotary cement kiln (wet process)	Nat. Gas	Low O_2, high air temp.
Steel open hearth furnace	NG + No. 6 oil	Low O_2
Steel reheat furnace	Nat. gas	3/27 BOOS
Steel soaking pit	Nat. gas	Low O_2
Aluminum melter	Nat. gas	Low O_2 (NO_x increased)
	No. 2 oil	Low O_2 (NO_x increased)
Black liquor recovery boiler	Liquor	Secondary air adjust
Wood bark boiler	Wood + NG	Low O_2
Wood bark boiler	Wood + coal	Low O_2
CO boiler	CO gas	Low O_2

TABLE VIE-4. (con.)

Device type	Fuel	Combustion modification[1]
Natural gas engine	Nat. gas	Fuel, air adjust
Diesel engine	No. 2 oil	Low inlet air temp.
Gas turbine combined cycle	Ref. gas	1/8 BOOS
Gas turbine combined cycle	Ref. gas	4/16 BOOS

[1] BOOS = Burners out of service.

TABLE VIE-5. KVB SUMMARY OF EMISSION MEASUREMENT INSTRUMENTATION

Emission parameter	Symbol	Measurement method	Equipment manufacturer
Nitric oxide	NO	Chemiluminescent	Thermo Electron
Oxides of nitrogen	NO_x	Chemiluminescent	Thermo Electron
Carbon monoxide	CO	Nondispersive infrared	Beckman
Carbon dioxide	CO_2	Nondispersive infrared	Beckman
Oxygen	O_2	Polarographic	Teledyne
Hydrocarbons	HC	Flame ionization	Beckman
Sulfur dioxide	SO_2	UV spectrometry	Du Pont
Sulfur dioxide Sulfur trioxide	SO_2 SO_3	Absorption/titration	Shell-Emeryville Absorption train
Total particulate matter		EPA Std. Method 5	Joy Mfg. Co.
Particulate size distribution		Cascade impactor, electro-balance	Anderson, Brink, Cahn
Smoke spot		Field service type smoke tester ASTM D-2156	
Opacity		EPA Std. Method 9	
Trace species and organics	TS&O	Source Assessment Sampling System (SASS)	Aerotherm

TABLE VIE-6. PENNSYLVANIA STATE UNIVERSITY FUEL-BURNER COMBINATIONS

	Small laboratory furnace	Large laboratory furnace	Power plant boiler
FUELS:			
Natural gas	x	x	
#2 Oil	x	x	x
#4 Oil	x	x	x
Emulsions (oil/water)	x	x	x
Dispersions (oil/coal)		x	x
Products of coal liquifaction	x	x	

to densely occupied areas. Consequently, both EPA and ERDA have sponsored research to determine the pollution from these sources. Table D5 in Appendix D lists some of the most recent work.

The Lawrence Berkeley Laboratory of the University of California in 1975 started its indoor air pollution research project, funded by ERDA. This is probably the most extensive continuing study in this neglected area.

The goals of the project are:

- To characterize indoor air pollution.
- To identify important sources, abundance, and fate of indoor air pollutants.
- To study the abatement of indoor air pollutants.
- To characterize exposure of the occupants to the important air pollutants.
- To study the health and welfare effects.
- To assess the impact of various energy-conservation strategies on indoor air quality.

Work to date has concentrated on examining in detail the sources, rates of emissions, dispersion, transformations, and the fate of gaseous and aerosol air pollutants in residential buildings. Future work will be expanded to include commercial buildings.

Both field studies and laboratory studies in experimental buildings are being carried out.

The staff feels strongly that the public health role of combustion-generated air pollution from indoor sources has been a seldom studied subject.

Pollutants being measured and the analytical methods used are shown in Table VIE-7.

Some results to date are interesting. Figure VIE-1 summarizes average indoor/outdoor data for gaseous air pollutant levels in the six houses under typical occupancy conditions of cooking and heating that have been studied so far. The results report, for the first time, elevated indoor SO_2 levels associated with gas stoves. Also shown are the high levels of NO and NO_2 observed in the one house where the effect of a forced-air gas-fire central heating system was studied.

The Berkeley people are deeply concerned with the Energy Conservation Standard for New Buildings Act of 1976. They are evaluating the impact on

TABLE VIE-7. LAWRENCE BERKELEY LABORATORY POLLUTANT SPECIES AND APPLIED ANALYTICAL METHODS

Pollutant	Analytical method
SO_x	UV fluorescence
NO_x	Chemiluminescence
O_3	UV absorption
CO	Nondispersive infrared absorption
Particulate size	Condensation nuclei formation electrical mobility analysis
Particle species - (total sulfur, total N, $SO_4^=$, NO_3^-, NH_4^+, Pb, Fe, Zn, and other elements, total carbon)	X-ray fluorescence, photoelectron spectroscopy, infrared, wet chemistry
HCN and NH_3	Methods being developed
Organics	Gas chromatography/mass spectrometry being developed
Meteorological measurements	
Air circulation, ventilation, and infiltration measurements	Air flow sensors, SF_6 as tracer gas for exchange rates

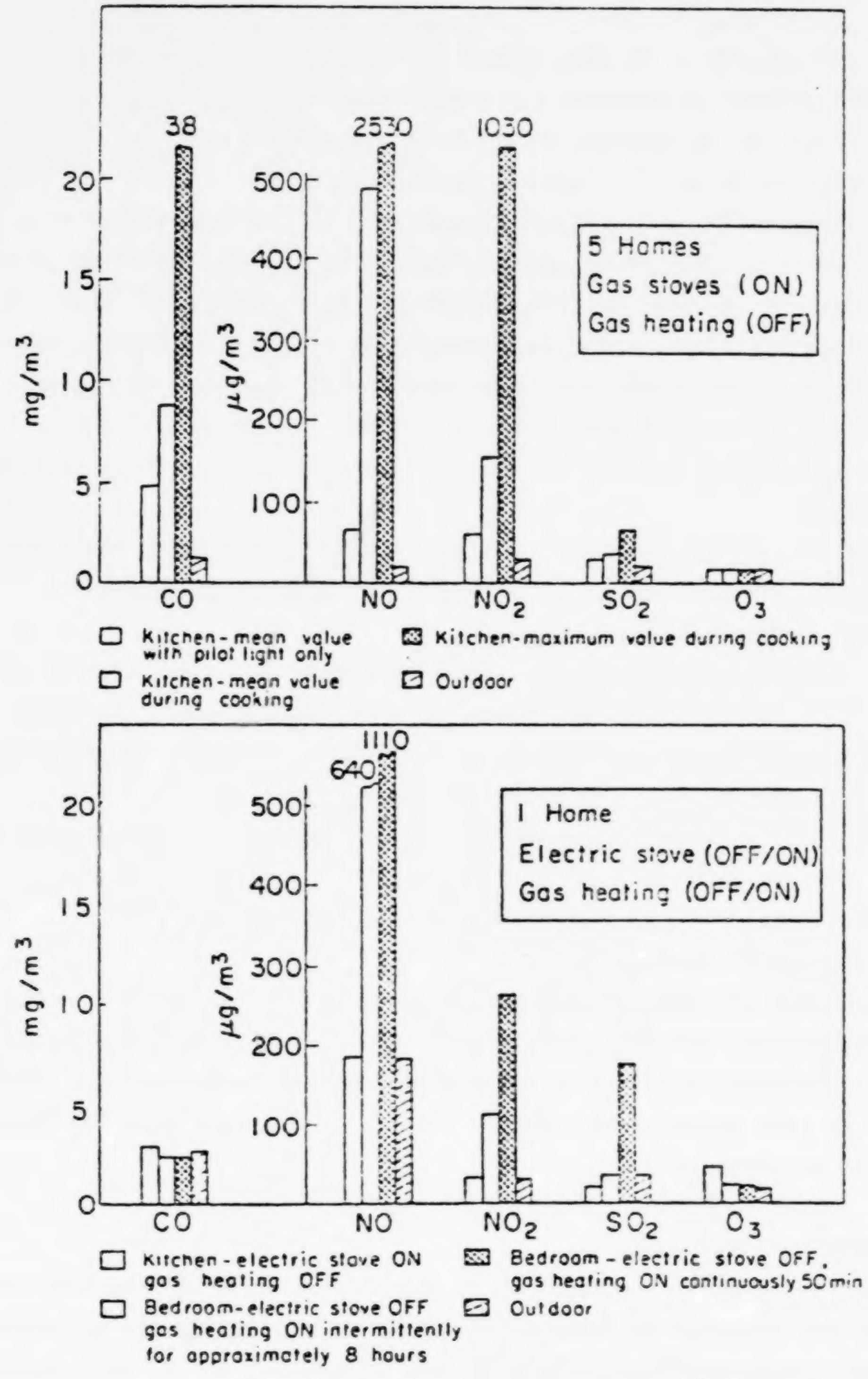

Figure VIE-1. Lawrence Berkeley Laboratory pollutant effects from residential gas devices indoor air quality of various energy conservation measures for buildings. State and Federal governments are considering limiting the air exchange rate in new houses to one-quarter to one-half air changes per hour rather than the existing rates of two air changes per hour or higher. Table VIE-8 shows the results obtained in a house measurement at a low air-change-per-hour rate.

A number of supporting projects are going on. One of these is the study of combustion-generated unknown organic nitrogen compounds. They are working on the hypothesis that very small amounts of highly carcinogenic materials may have more serious consequences for human health than the pollutants presently recognized. Health effects will be assessed. The school of public health is developing protocol for the conduct of epidemiological studies in support of the program.

New methods for sampling and measurement for extremely small quantities of organic nitrogens are being developed to support this program.

5. Fuel Characterization

EPA has sponsored many detailed investigations to relate fuel properties to their pollution potential. These include trace element and mineral content determinations in coal, the emissions from hydrothermally treated coal, emissions from residual oil, and alternate fuels.

EPRI has recently initiated a 5-year project to develop methods for the nondestructive assay of coal.

These projects are listed in Table D6 of Appendix D.

6. Measurement Methods

Both EPA and EPRI are sponsoring major efforts to develop sampling and analysis methods for POM, other organics, and trace elements. In addition, EPA is sponsoring research to develop measurement techniques for fugitive emissions from process and effluent streams. These projects are listed in Table D7 of Appendix D.

F. TRANSPORT AND FATE

As can be seen from Table D8 in Appendix D, both EPA and ERDA are sponsoring many projects to determine how various pollutants are propagated through the environment and what happens to them ultimately in the environment. Perhaps the most ambitious undertaking is the ERDA-sponsored Multistate Atmospheric Power Production Pollution Study (MAP3S), which is being coordinated by

TABLE VIE-8. LAWRENCE BERKELEY LABORATORY AIR POLLUTANTS OBSERVED FROM A GAS STOVE OPERATING IN AN EXPERIMENTAL ROOM AT A CONTROLLED AIR EXCHANGE RATE OF 1/4 AIR CHANGES PER HOUR*

Parameter measured	Background		3-hour measurement period		Typical peak polluted urban levels
	Indoor	Outdoor	Gas oven on (1-hour average)	Gas oven off (2-hour average)	
CO (ppm)	.7	.8	35	60	10 - 20
NO (ppm)	.005	.040	0.8	1.2	.2 - .5
NO_2 (ppm)	.045	.050	2.5	2.5	.2 - .5
SO_2 (ppm)	.005	.005	.010	.020	.1 - .5
S (as SO_4^{--}) ($\mu g/m^3$)	< 1	< 2	13	14	10 - 20
Aitken nuclei (no./cm^3)	20K	40K	3000K	200K	100 - 4000K
Submicron aerosol mass median diameter (μm)	.2-.3	.2-.3	.08	.2	.2 - .4

*Measurements at center of 27 m^3 room for 3-hour period (gas stove oven operating for first hour only).

the University of California's Livermore Laboratory. The MAP3S goal is to improve understanding of the temporal and spatial relationships between ambient levels and emissions from utilities in order to provide a better basis for modeling more accurately the changes in pollutant concentration and type, precipitation chemistry, and atmospheric behavior that impact health and ecology. This would allow evaluation of alternate strategies in the generation of power with fossil fuel in the northeastern United States. Pollutants under observation are sulfur dioxide, sulfites, sulfates, and other sulfur oxides; nitrogen oxides and their secondary reaction products, including oxidants; hydrocarbons, including POM; trace inorganics; and particles including carbon or soot.

The program is divided into three subprograms:

- Characterization--measurement of chemical and meteorological variables that determine pollutant species distribution;
- Field experiments--design and execution of atmospheric research experiments necessary for understanding processes and mechanisms of pollutant transport and transformations; and
- Simulation--mathematical modeling.

Budgeting for FY1977 was approximately $3 million with allocation to tasks as shown in Table VIF-1. Organizations participating in the program are shown in Table VIF-2.

The EPA is carrying out a comprehensive air and water pollution monitoring program, the Western Energy/Environment Baseline Monitoring Study, to determine the long-term impacts of energy resource development in the southwestern United States, emphasizing the Four Corners area, the Northern Great Plains area, the Oil Shale areas of Colorado and Utah, and the Black Mesa area of Arizona. Major project components of this program have been listed in Table D8 of Appendix D. In addition, EPA has sponsored investigations by TVA of the atmospheric transformation of emissions from coal-fired power plants, and investigations by several universities of sulfur oxides in aerosols and plumes and mesoscale sulfur budgets.

EPRI is sponsoring a massive ($5.5 million) program, The Sulfur Regional Experiment (SURE), to define regional, ambient concentrations of secondary pollutants (e.g., sulfates) in terms of local emissions of primary precursors (e.g., SO_2). Although the emphasis is on sulfates, other pollutants are being

TABLE VIF-1. PERCENTAGE BREAKDOWN OF FUNDING FOR MAP3S RESEARCH PROGRAM BY TASK*

Task 1:	Power plant emissions	2.5%
Task 2:	Other related emissions	
Task 3:	Pollutant characteristics	10.0%
Task 4:	Pollutant distribution	15.0%
Task 5:	Vertical and long-range transport	10.0%
Task 6:	Pollutant transformation	20.0%
Task 7:	Dry deposition	2.5%
Task 8:	Pollutants and precipitation	15.0%
Task 9:	Weather and climate effects	10.0%
Task 10:	Numerical modeling	15.0%

*Most of the funding for Task 9 is for completing METROMEX analysis and will be transferred to Task 8 in FY 1978 for precipitation chemistry analysis around Chicago.

TABLE VIF-2. PARTICIPANTS IN THE MAP3S PROGRAM, INCLUDING ERDA/DBER-FUNDED UNIVERSITIES WITH PROGRAMS CLOSELY RELATED TO MAP3S OBJECTIVES

ERDA National Laboratories
- Argonne National Laboratory (ANL)
- Battelle Pacific Northwest Laboratory (PNL)
- Brookhaven National Laboratory (BNL)
- Health and Safety Laboratory (HASL)
- Lawrence Berkeley Laboratory (LBL)
- Lawrence Livermore Laboratory (LLL)

Other Organizations
- Illinois State Water Survey (ISWS)
- NOAA Air Resources Laboratory (ARL)

Universities
- Brigham Young University
- Cornell University
- Drexel University
- Pennsylvania State University
- State University of New York
- University of Michigan
- University of Virginia

measured. The program elements of SURE are: (1) a ground- and air-based measurement program; (2) an emissions inventory; and (3) development of a model to predict regional concentrations as a function of local emissions. Fifty-four ground stations are more or less randomly distributed across the eastern States with the westernmost station at Madison, Wisconsin, the easternmost at Fall River, Massachusetts, the southernmost at Atlanta, Georgia, and the northernmost at Jay, Maine. Four times a year two aircraft will be used over and near selected ground stations to fly vertical spiral patterns ranging from 500-ft to 10,000-ft altitudes in order to vertically profile pollutant distributions. This program was begun late in 1976 and is scheduled for completion early in 1980. Prior to the field work, EPRI had sponsored a 1-year $250,000 planning study by Environmental Research and Technology.

A study of the interaction of stack gas plumes and cooling water plumes is being carried out by Pennsylvania State University. The sampling is done by a completely equipped aircraft including an isokinetic sampler. The formation of SO_2 and SO_3, as well as particle mass and size behavior, is being measured to determine interreactions. A companion study is the production and growth of sulfate particles in the emissions from coal-operated power plant plumes.

Another research project being carried out at Penn State is concerned with the heterogeneous reactions of various air pollutants in water bodies.

G. HEALTH EFFECTS

Recent major projects are listed in Table D9 of Appendix D. Many of these are summarized below. The health effects research component Federal Interagency Energy/Environmental Research Development Program is being coordinated by the Office of Energy, Minerals, and Industry (OEMI) with the Office of Research and Development (ORD) of EPA. The research is organized into five objective areas: identification of hazardous agents; dose and damage indicators; metabolism of hazardous agents; evaluation of hazards to man; and damage, repair, and recovery mechanisms. Current research emphasizes those pollutants associated with fossil fuel combustion (both conventional and advanced), coal conversion, and energy conservation efforts. A synopsis of this program giving a complete listing of Federal agency-sponsored research covering FY1975 to FY1977 has been presented in J. Dorigan and H. Mahar, "Health Effects Research Program Fiscal Year 1975-1977 Summary," The MITRE Corporation, METREK Division, August 1977 (EPA Report Number EPA-600/7-77-112, sponsored by OEMI on Contract Number 68-01-3539).

1. EPRI--Health Effects Program

EPRI is now doing detailed planning for a major study. This may well turn out to be the most important single health effect project in the country. All of the work, of course, is on the effect of emissions from utility sources. The work planned includes animal toxicological studies, human experiments, and epidemiological studies. The planning document should be completed and available very shortly. The CPA program should establish contact with EPRI and follow this project closely.

In all of the following programs funding is on an annual basis.

2. University of California, Livermore--Trace Elements in Major Food Chains (ERDA, $224K)

Project description: Assess the impact of trace element releases due to energy production on the water/soil/foliage/cows/milk food chain. The project will establish the suitability of milk as an indicator of toxic heavy metal dose to a given area exposed to specific energy-related pollution.

3. ERDA Health and Safety Laboratory--Assessment and Control of Non-Nuclear Air Contaminants (ERDA, $80K)

Project description: Methods are developed for assessing and reducing exposures to man from hazardous air contaminants arising from energy production. The reliability of techniques for monitoring exposures to toxic substances is improved through studies of the performance of monitoring instrumentation in practical applications. Methods of measurement are developed to improve definition of hazardous aerosols through proper recognition of the effects of physical and chemical properties on respiratory tract deposition and retention.

4. EPA-HERL--Study the Health Effects from NO_2, CO, and Certain Hydrocarbons in Newly Insulated Homes (EPA, $193K)

Project description: The purpose of this task is to determine if better insulation of homes will contribute to higher levels of certain indoor air pollutants with commensurate adverse health effects. Measurement of the pollutants will be taken at regular intervals, both before and after the insulation of the home. Biological specimens and information on certain symptom states will be collected at the same time.

5. University of California, Davis--Assessment of Health Effects of Energy Systems (ERDA, $67K)

Project description: The purpose of this study is to analyze and assess the comparative effects of effluents associated with electrical power generation as they relate to risks to human health. Data will be collected from literature and from investigators to develop mathematic models for the predictions of risks to man for scaling from animal species to humans.

6. Battelle-Northwest--Toxicity of CO, NO_x, SO_x, and Fly Ash (ERDA)

Project description: This project will evaluate in an animal model acute and chronic effects of exposure to pollutant atmospheres which could realistically develop around large-scale fossil-fuel-burning power plants. From these studies it will be determined whether the increased output of a variety of combustion products from fossil fuel power plants may constitute health problems of greater magnitude than those anticipated from our present knowledge of the effects of individual pollutants; and whether present air quality standards for individual agents are adequate when they are released in combination with other agents. Without such investigations the total population will be chronically exposed to this combination of pollutants without knowledge of the consequences. Pulmonary deposition, physiological alterations, and early biochemical changes related to impairment of lung functions will be measured.

7. Battelle-Northwest--Lung Toxicity of Sulfur Pollutants (ERDA)

Project description: This project will provide information on the interaction between the physiologic event of bronchoconstriction caused by exposure to sulfur pollutants and related physiologic and biochemical changes that may place sensitive individuals at risk from heart attacks or exacerbation of bronchitis or emphesema. The primary output will be to define biochemical agents responsible for changes in pulmonary functions caused by exposure to sulfur pollutants. As a consequence of the initial findings, possible beneficial effects of inhibiting the action of these responsible agents will be evaluated to determine whether individuals highly sensitive to the pollutants can be protected. A means of protecting the health of sensitive individuals in the human population may be available.

8. Battelle-Northwest--Factors Influencing Cross-Placental Transfer and Teratogenicity of Metallic Pollutants (ERDA, $80K)

Project description: This project will be concerned with heavy metals for which there is direct or inferential evidence of deleterious effects on prenatal development. It will define the specific influences of factors that affect the qualitative and quantitative aspects of the cross-placental transfer of certain of the heavy metals associated with energy production and their distribution throughout the feto-placental unit as a function of time after exposure to define the tissues at risk and provide quantitative estimates of dose. The intravenous, oral, and inhalation routes of administration, which will provide a difference in the rate at which the metals are presented through the placenta as well as a possible difference in their chemical binding in blood, will be compared. A low dose level as well as one in the teratogenic range will be studied.

9. Lovelace Foundation--Metabolism of Inhaled Trace Metal Effluents from Combustion Processes (ERDA-EPA pass thru, $111K)

Project description: Nickel, beryllium, cadmium, tin, animony, lead, and bismuth have all been identified in environmental air samples and all have known toxic properties. Since the toxicity of metals such as these is dependent upon both the exposure and deposited doses of the toxicant in lung and other tissues of the body, it is necessary to develop detailed metal dose distribution relationships to correlate pathologic observations with inhaled air observations.

10. Lovelace Foundation--Develop Instrumentation and Methods to Identify, Measure, and Analyze Energy Related Aerosols and Particulates in Relation to Direct Effects on Health (ERDA-EPA pass thru, $141K)

Project description: Fuel source and combustion technologies that most significantly influence the nature of airborne effluents will be identified using newly developed analytical procedures and sampling instruments. Materials collected will be used in a selective way for metabolic and effects studies in animals.

11. University of California, Davis--Biochemical Effects and Reactions of Sulfur Dioxide (NIEHS, $33K)

Project description: The first phase consists of a study of the free radical damage of cell components caused by the aerobic oxidation of bisulfite or sulfite ions. The radicals, which are generated during the aerobic oxidation of sulfite, are particularly suspect as toxic agents that may destroy amino acids, hormones, lipids, and coenzymes. The next phase is to examine the in vitro effect of sulfate ion on various enzyme and membrane systems and to characterize sulfite oxidase from plant sources. The third phase will involve the in vivo effect of SO_2 on the metabolism of harvested fruits.

12. University of California, Department of Medicine, Los Angeles--Environmental Trace Metal Intoxications of the Kidney (NIEHS)

This study explores the biochemical pathogenesis of renal dysfunction secondary to trace metal intoxication. The majority of studies will be performed on experimental animals (rats). The removed kidneys will be examined by electron microscopy and by emissions spectroscopy or trace metal analysis. Also, patients with acquired renal dysfunction secondary to industrial exposure from trace metals will be studied in detail.

13. Bowman Gray School of Medicine--Effect of NO_2 Induced Lesions in Lung Macrophages (NIEHS, $34K)

The research is designed to study biochemical nature of the lesions induced by nitrogen dioxide in alveolar macrophages.

14. Harvard University--Factors Effecting Irritant Potency of Gases and Aerosols (NIEHS, $69K)

The work proposed is part of a long range program of study of the irritant potency of pollutants in urban and industrial environments. Correlations will be made of the physical or chemical factors of the exposure environment with observed biological responses. Priority is given to the effect of particle size on the irritant potency of aerosols and the possible potentiation of irritant gases by aerosols. The biological assay used is the measurement of the mechanics of respiration of guinea pigs before, during, and after exposure to pollutants. Studies will be made of the joint toxic action of SO_2 and sulfuric acid for a range of particle sizes of sulfuric acid. Nitrogen dioxide alone and in combination with aerosols and sulfur dioxide will also be studied.

15. Appalachian Laboratory for Occupational Respiratory Disease--Mortality Study of TVA High Risk Workers (Public Health Service, $236K)

Project description: The primary purpose of this study is to measure specified effects such as decreased longevity, premature death, deaths from pulmonary diseases, and early retirement due to disability attributed to such diseases on high risk workers in coal-fired steam electricity generating plants who have been exposed to specific pollutants such as SO_2 and NO_x for varied durations and intensities. Data will also be collected on neoplasms of the respiratory system and on diseases of the heart.

16. National Institute for Occupational Safety and Health--Sulfuric and Acid Sulfates, Occupational Health Epidemiological Study (EPA pass thru, $175K)

Project description: EPA, in its test report (1970-1971), indicated that soluble and insoluble sulfates have a more adverse effect on human health than particulates or SO_2. The first phase of this project will determine exposures to a variety of soluble and insoluble sulfates and sulfuric acid in a number of industries. These data will be used to choose populations for mortality studies beginning in FY1977.

17. University of Cincinnati, School of Medicine--Chemical Characterizations and Toxicity of Metal Binding Components of Emissions from Mobile and Stationary Energy Sources (EPA, $115K)

Project description: The overall objective of this study is to isolate and characterize metal-binding agents from mobile and stationary exhaust emissions and to assess the biological damage that may be caused by the interaction of these agents with essential metals metabolism.

18. University of Cincinnati--Electroencephalographic and Behavorial Studies of Rats During Long Term Continuous Exposure to Sulfur Dioxide and Particulate Matter (HERL/Cincinnati)

Project description: Experiments are in progress that were designed to determine the behavioral and electroencephalographic effects of chronic (90-day) exposure to sulfur dioxide, sulfuric acid, sulfate particulates, and automobile exhaust emissions. Measurements of respiratory function and blood gas analyses are being done on rats periodically during and following the 90-day exposure period.

19. UCLA, School of Medicine--Effects of Pollutants from Energy Consumption and Environmental Trace Metals on Lung Metabolism

Project description: The objectives of the work are to determine qualitative and quantitative biochemical alterations in the lungs of experimental animals exposed to pollutants related to energy consumption. The effects of nitrogen oxides, ozone, sulfur oxide, sulfuric acid, and other energy consumption-related pollutants will be studied. Lung effects will be delineated using sensitive biochemical parameters. The results may form a basis for making predictions of possible effects of short-term and long-term exposures to these pollutants and to help establish environmental quality standards. The effects of trace metals will also be studied.

20. Merlin University--Study of the Effects on Asthmatics of Pollutants Resulting from Converting to Coal Combustion in a Power Plant (EPA, Washington, $86K)

Project description: A group of asthmatics living in close proximity to a power plant will be followed for daily symptoms, reporting for 3 months prior to and 1 month after conversion from combustion of oil to coal in the power plant. Aerometric measurements will be made and health data will be correlated with the aerometric data.

21. Northrop Service, Inc.--Cytotoxicity Evaluation of Selected Sulfates and of Source and Ambient Air Samples (HERL/RTP, $100K)

Project description: The relative cellular toxicity of selected compounds including inorganic metallic sulfates and crude samples from stationary sources and ambient air will be determined. An assessment will also be made of the potential carcinogenicity of these samples by use of neoplastic transformation bioassay systems.

22. IIT Research Institute--Evaluate Effects of Chronic or Intermittent Exposure to Respirable Particles and Mists Using Mouse Pulmonary Infectivity Model

Project description: The effect of acute chronic and intermittent exposure to respirable particles (carbon and sulfuric acid mists) on the resistance of mice to pulmonary infections will be examined. Exposures will be for 6 hours per day. At various times the animal will be removed and challenged with an infectious microorganism. A no-effect level will be determined. Also, mortality rates will be determined. Host defense alteration measurements will include humeral and cell-mediated immunity response, phagocytic and bacteriocidal activity of lung defense cells.

23. HERL/Cincinnati--Comparative Toxicological Assessment of Fly Ash from Western and Eastern Coal (In-house, $69K)

Project description: The potential hazards of emissions from western versus eastern coals will be evaluated. Apparently no data are presently available from western coal sources. Fly ash samples will be collected directly from the effluent of power generation plants downstream from an electrostatic precipitator. The ash samples from both eastern and western coal will be analyzed for trace elements as well as major components. One study will establish lethal concentrations from acute exposure (1-7 days). Another study will be on chronic effects (6-11 months), with concentrations of fly ash aerosols ranging from just below lethal levels down to that found under ambient conditions in the immediate vicinity of the generating plant. At least three species of animals will be tested. Measurements will include survival, growth, pathology, and blood analyses. Tissue analysis for trace metals will also be made.

H. ECOLOGICAL EFFECTS

1. The Pennsylvania State University, Center for Air Environment Studies

The center was established in 1963 in recognition of the need for interdisciplinary attacks on environmental problems and the necessity for intercollege cooperation. The technical staff includes university personnel who receive all or part of their salary from the center funds or grants. During the 1976 fiscal year, 45 faculty members representing 20 academic departments conducted air pollution research and participated in the development of air pollution courses. Research areas are heavily weighted toward the effects of air pollutants on vegetation and on small particle technology. A few of the projects dealing with ecological effects are discussed below to illustrate the nature of the research conducted.

One project, entitled "Air Pollution Effects on Woody Plants," has the long-range objectives of development of air quality criteria with respect to the effects of photochemical air pollutants on woody vegetation; an understanding of the influence of various environmental factors on the response of plants to photochemical air pollutants; the development of a list of woody ornamental plants that are resistant to photochemical air pollutants under a variety of environmental conditions, which could be used as a basis for recommendation to land owners, home owners, nurserymen, foresters, municipalities, and governmental agencies in areas of potential air pollution problems; and, ultimately, the development of models that could be used to predict the occurrence of vegetation injury and damage in a given area.

Another study is titled "The Establishment of a Vegetation Exposure Facility and Initiation of Energy Related Research Involving Sulfur Dioxide."

The facility is now in operation. Plants may be exposed at various, carefully controlled and monitored levels of SO_2, temperature, humidity, and light. A study has been completed in which the influence of SO_2 on 13 varieties of Christmas trees was determined. Bean plants are now being exposed to different dosages of SO_2 at varying humidities and temperatures. Dosage response curves vary with leaf age, leaf stage, humidity, and temperature.

The center's efforts are probably typical of those of a number of other universities.

Funding for the following projects, except 9., is on an annual basis.

2. Tennessee Valley Authority--Characterize and Quantify the Transfer, Fate, and Effects of SO_x, NO_x, and Acid Precipitation in the Terrestrial Ecosystem Representative of the Tennessee Valley Region (EPA, $184K)

Project description: A series of forested watersheds is being established, instrumented, and calibrated in order to evaluate atmospheric inputs of SO_x and NO_x. An acid rain simulator will be utilized to evaluate plant and soil response to precipitation pH. A compartmental mass balance will be developed for selected elements in several biotic and abiotic compartments. This information will be used to evaluate atmospheric input in relation to system alteration and response.

3. Tennessee Valley Authority--Filtered and Filter/Unfiltered Exposure Chamber Studies of Effect of Coal-Fired Power Plant Emissions on Crop and Forest Species of Economic Importance in Southeastern United States (EPA, $150K)

Project description: Impacts will be determined on yield and crop appearance through the use of field (polluted) air exclusion system and charcoal filtered air greenhouses. The relationship between exposure, dose, and yield will be determined. The effect of other environmental parameters modifying plant response to SO_2 will be determined. In its first year, 30 air filtration systems were established and exposure data obtained for soybeans and cotton. In the second year, conifers and small grains were added for study.

In the future, other varieties of soybeans and cotton, other locations, varying soil fertility, and soil pH will be tested.

4. Tennessee Valley Authority--Determine Dose-Response Kinetics for Effects of Atmosphere Emissions from Coal Fired Power Plants on Soybeans and Other Crop and Forest Species of Economic Importance in Southeastern United States (EPA, \$45K)

Project description: Determine the individual and combined effects on vegetation of SO_2, NO_2, and O_3 exposures at concentrations, dosage rates, and environmental conditions typically occurring during surface exposures in the vicinity of large coal-fired power plants. A fumigation chamber within a growth chamber and a pollutant injection system capable of duplicating actual field fumigations will be used. Crop plants will be exposed to power plant effluents and other atmospheric pollutants to determine their effects on yield and plant sensitivity.

5. Tennessee Valley Authority--Evaluate the Beneficial Effects of SO_2 and Other Pollutants Emitted from Steam Plants on Crops and Forest Species, Particularly Soybeans and Pines

Project description: Sulfur and other plant nutrients in rainfall and dry particulates are collected and analyzed. In addition, four methods of measuring SO_2 taken up by vegetation will be evaluated and the best selected for use at various locations to measure SO_2 uptake by soil. Samples of native soil will be collected on different radials from coal-fired power plants and the sulfur content compared with samples selected from areas remote from the power plant. The consequences of a possible sulfur deficiency occurring if this source of sulfur is eliminated can be evaluated.

6. UCLA--Effects of Non-Nuclear Pollutants on Arid Environments (ERDA, \$71K)

Project description: The main objective of this study is to examine the potential effects of coal ash deposition on desert ecosystems. Field plots will be established at the Nevada test site. Ash from plant precipitators will be applied to plots each month. Application rates are set so as to achieve target levels in 2 years. Each set of three perennial plants is treated, and control plots will be compared in terms of growth, reproduction, and survival. Work will evaluate the relation of effects of ash on desert plants (both stimulative and deleterious) to varying dose regimens and will contrast these levels to those expected as a result of operation of coal-burning power plants in deserts. The levels will be related to those actually encountered in the vicinity of the plants or to projected levels following 30 years of plant operation.

7. University of California, Livermore--Effects on California Marine Biota of Effluents of Power Plants (ERDA, $51K)

Project description: The objectives are to determine the toxic effects on marine organisms of pollutants released from power plants. Both the effects of corrosion products that are leached into the water circulating in the cooling systems and of chemicals that are added to it and the effects of particles released from the stacks and deposited directly or indirectly into the water are being considered. Organisms are selected representative of different trophic levels and different feeding types. Mortality, pollutant concentrations in tissue, and the effects of the pollutants on important physiological processes such as respiration, circulation, and reproduction are monitored. Experiments are being carried out to establish the toxicity of copper to abalone and mussels, and the effects of temperature and increased level of copper toxicity in mussels and abalone are being measured. The sensitivity of adult pacific herring to copper will be established also.

8. Johns Hopkins University--The Effects of Energy Related Activities on the Plankton of the Chesapeake Bay (ERDA, $130K)

Project description: The project attempts to identify the major factors regulating phytoplankton primary productivity during each season in Chesapeake Bay and on the adacent continental shelf. Also, the effects of heated power plant effluents and cooling tower effluents on bacterial processes in Chesapeake Bay are measured. Populations of phytoplankton and bacteria employing both experimental introduction of selected pollutants, such as heat, acid, biocides, hydrocarbons, and heavy metals, and measurements on natural populations subjected to power plant effluents are measured.

9. University of Wisconsin--The Impact of Coal Fired Power Plants on the Environment

This is a long-term study of the effects of operation of a large coal-fired power plant on the ecology of a wetlands area. The site is the area around the Columbia Generating Station of the Wisconsin Power and Light Company, located near Portage, Wisconsin, on the Wisconsin River. From January 1, 1971, to July 21, 1975, the study was funded by a consortium of the Wisconsin Power and Light Company, Madison Gas and Electric Company, and Wisconsin Public Service Corporation at about $45,000 per year. In 1975, a grant was negotiated with EPA that increased annual funding approximately tenfold and greatly expanded the scope and depth of research coverage. The objectives of the EPA grant include:

- detailed modeling of the flow of chemical species through the coal-fired generating station and into the wetlands ecosystem;
- assessment of the impact of the generating station on the aquatic and terrestrial environment; and
- development of a data base and siting criteria protocol for similar future facilities.

The work from 1971 through 1974 established baseline data for flora and fauna indigenous to the area and monitored for any discernable effects of the construction phase. In 1974 a 525-MWe unit was put into operation. This plant burns low sulfur (< .75 percent) western (Montana) coal. A second 525-MWe unit is scheduled to start operation in March 1978.

Because of the low sulfur content of the coal, the only flue gas pollutant control equipment presently used is an electrostatic precipitator.

Project activity is grouped into four major areas:

- identification and quantification of chemical species, mass balances, transport, and fate;
- determination of biological effects in aquatic and terrestrial ecosystems;
- synthesis and integration of subproject results to provide a comprehensive assessment of ecological impact; and
- development of siting criteria for similar installations.

The chemical species area has included mass balance studies for the ashpit and cooling lakes, studies of seepages of metallic elements and sulfate into nearby wells, and a plume chemistry study. In the biological effects area, detailed studies of the accumulation and metabolic transformation in several types of fish of typical organic species have indicated that bile accumulation provides a very large degree of concentration for some species and may be a very sensitive indicator of the presence of organic pollutants. Bioassays of various species in small streams and the wetlands adjacent to the cooling lake and ashpit drain are being used to determine what effects, if any, seepage and drainage are having on nearby fauna. To assess effects on flora, alfalfa, white pines, and lichens in the area are being monitored.

To date, research efforts have resulted in over 100 publishable manuscripts.

10. Argonne National Laboratory--Energy-Related Environmental Research on the Great Lakes. Fate and Effects of Non-Nuclear Pollutants (ERDA, $26K)

Project description: Some objectives are to describe the biogeochemical cycling of pollutants, to define hydrodynamic transport of pollutant types, and to assess the ecological and human health effects of these pollutants. The most biologically active and toxic pollutants will be identified. Their transport and fate in the Great Lakes will be delineated. Emphasis will be placed on the highly populated, industrialized southern basin of Lake Michigan where measure sources and sinks are known.

11. Argonne National Laboratory--Land and Fresh Water Environmental Sciences, Impact of Fossil Fuel Utilization on Terrestrial Ecosystems (ERDA, $147K)

Project description: The objective is to gather information needed to assess the impact of fossil fuel pollutants on agricultural crops in the midwest. Both gaseous and particulate pollutants are considered. Both controlled experiments (growth chambers) and field studies will be carried out. The effects of interest are photosynthesis and growth, uptake and biotransformation of pollutants, and parietal sensitivity. Chronic effects, uptake-response relationship, and mechanisms of toxicity of sulfur oxide on important crop plants will be described. Also, interactions between pollutants, environmental factors, and parietal sensitivity will be studied.

12. Brookhaven National Laboratory--Effects of Acid Rain on Terrestrial Ecosystems (ERDA, $176K)

Project description: Poorly buffered, sandy soil ecosystems such as those on Long Island are especially affected by energy-related acid rainfall and acid particulates. It will be determined what the effects are on plant systems, soil chemistry, soil microflora and the interrelationship of these three. Constituents and rates of local (Long Island) rainfall will be determined. Plant foliage will be exposed to simulated acid rain/aerosols of various concentrations for various durations/intervals to determine physical/chemical injury effects, threshold limits with no injury effects, changes in plant growth, and vegetative yields. Studies will be made of the changes in plant cell permeability by monitoring foliage leachates.

13. Los Alamos Scientific Laboratory--Ecological Fate and Effects of Trace Contaminants from Coal Combustion and Processing

Project description: The objectives of this project are to define meteorological influence on the source of airborne contaminants from coal-fired power plants, assess the effects of localized and widespread deposition of contaminants upon the ecosystem of the airshaft surrounding the Four Corners Region, integrate several disciplines in a systems approach to a sensitive environment in such a way as to mitigate the extraction utilization and export of resources for the Los Alamos region.

14. Battelle, Pacific Northwest Laboratory--Plant Heat and Chemical Effluent Effects on Selected Marine and Estuarine Communities (ERDA)

Project description: The objectives are to identify the forms of chemicals in power plant effluents, e.g., chlorine, copper, chromium, and nickel, that are biologically active, to determine how they are modified by physical parameters such as heat, and to determine their single and combined effects on important marine and estuarine species and communities. Short-term laboratory experiments will lead into long-term low-contaminant-level investigations. These will be compared to field verification studies of existing power plant effluents. The anticipated results are the establishment of realistic water quality criteria for thermal discharges, the optimization of biocide dosages when combined with other chemicals having known toxic effects, the relative toxicities of chemical releases and how they are modified by heat, and long-term, low-level effects of combined releases on marine and estuarine communities.

15. Du Pont de Nemours--Trace Metal Cycling and Effects on Terrestrial Ecosystems in the Southeastern United States (ERDA, $130K)

Project description: The objectives of this study are to determine the influence of trace metals released from coal-fired power plant stacks upon terrestrial ecosystems typical to the southeastern United States and to evaluate the possibility of reclaiming abandoned ash basins for agricultural use.

One study is focused on the environs of a large power plant that has consumed about 400,000 tons of coal per year since 1952 and that operated without electrostatic precipitators until near the end of 1975. Stack gas sampling and coal consumption will be used to estimate total releases during 23 years of operation. The concentration of minor trace elements in soil, groundwater, and terrestrial vegetation and animals will be determined. Secondly, reclamation of a large ash basin abandoned about 10 years ago will be studied. Growth and chemical composition of trees, grasses, and legumes grown on an abandoned ash basin with the same grown on agricultural soil will be compared.

16. Argonne National Laboratory--Assessment of Environmental Conditions of the Great Lakes in Relation to Power Production.

Project description: The objectives are to: (a) develop, synthesize, and integrate information for baseline characterization of regional environmental resources within each of the Great Lakes watersheds; (b) assess the current and projected impacts of regional power developments on these resources; and (c) evaluate control technology and resource management options for mitigating adverse impacts associated with power supply and conservation technology developments in each region.

17. Oak Ridge National Laboratory--Environmental Effects of Cooling Tower Drift (ERDA, $90K)

Project description: The key objective is to develop knowledge necessary to assess the impacts of cooling power operation on terrestrial ecosystems. Primary tasks are directed at obtaining a predictive capability of drift transport, deposition, interception, and retention by vegetation and soil and the effects of trace contaminants in drift on biota. An additional objective is that of comparing model estimates of drift deposition with biological data. Studies include quantification of drift toxicant, i.e., chromium and zinc, in air, soil, groundwater, plants, and small animals in the vicinity of large, megawatt-size cooling towers. Response of biota is determined through laboratory and field studies. The results are intended for integration to resolve ecological questions concerning drift toxicant contamination, cycling, and potential for adverse effects. Products of the research will be applicable to utilities and industries in siting of cooling towers, to establishing monitoring programs and guidelines, and to State and Federal regulatory agencies in environmental impact assessments.

18. Oak Ridge National Laboratory--Environmental Fate of Emissions from Coal Combustion Plants (ERDA, $200K)

Project description: (a) Evaluate the role of a forested landscape in the removal of airborne trace contaminants. (b) Determine the physical/chemical characteristics of source emissions and atmosphere inputs of selected trace contaminants to a terrestrial landscape. (c) Optimize the use of an atmospheric transport model to compute inputs of trace contaminants of terrestrial landscape from selected point sources for determining if atmospheric emission and landscape deposition of trace contaminants derived from coal-fired power plants result in significant net annual and/or long-term accumulation of these contaminants on a representative east Tennessee watershed. The technical approach involves use of an intensively instrumented and well characterized forested catchment located within 15 km of two large coal-fired power plants. Measurements of selected trace contaminants in air, rain, on leaf surfaces, and in stream water are made on a basis designed to elucidate transport, deposition, and cycling of these contaminants on a landscaped scale. Full-scale aerosol-canopy interactions studies were begun in August 1976. Initiation of plume sampling for source characterization was begun in September 1976. Note that this program as well as probably many other ecological studies provides emissions assessment data frequently with emphasis on trace emissions such as trace elements. Thus, we have another source for emissions data banks.

19. Oak Ridge National Laboratory--Ecological Effects of Coal Combustion: Response of Vegetation to SO_2, O_3, and Acid Precipitation (ERDA, $69K)

Project description: The project will examine physiological responses of plants as indicators of acute and subacute response of plants to air pollution stress. Primary emphasis will be placed on determining the physiologically significant features of pollutant doses. Exposures will be made through use of a programmable acid rain simulator as well as in the field.

20. Tennessee Valley Authority--Fisheries Impact of Steam Electric Power Plant Operation (TVA, $1,575K)

Project description: If the funding we have recorded is correct, this is certainly the largest single ecological study we have seen. The project objectives are to determine the magnitude and significance of impact on the fisheries resource of TVA reservoirs resulting from operation of steam-electric power plants. Impacts considered include effects of thermal discharges and effects of intake design and operation. The approach is as follows: (a) field sampling of adult fish to determine abundance, avoidance/attraction to thermally influenced areas, effects of thermal discharge on growth, reproduction, parasites, and disease; (b) weekly impingement counts with data (annual basis) related to standing stock biomass and annual production; and (c) sampling ichthyoplankton in reservoir and intakes to estimate percentage entrainment.

I. MULTIMEDIA GOALS

Multimedia Environmental Goals (MEG's) are levels of contaminants or degradents (in ambient air, water, or land or in emissions or effluents conveyed to ambient media) that are judged to be (1) appropriate for preventing certain negative effects in the surrounding populations or ecosystems, or (2) representative of the control limits achievable through technology.

Establishing Multimedia Environmental Goals is an integral part of the environmental assessment methodology that is currently being developed under the guidance of the Fuels Process Branch of IERL/EPA at RTP. Environmental assessment involves:

1. The determination of contaminant levels associated with emissions and effluents from a point source.
2. Comparison of those determinations with desirable control levels.

The need for MEG's arises in this latter aspect of environmental assessment.

The MEG's program has been conceived to supply sets of control goals for specific chemical contaminants, complex effluents, and nonchemical degradents based on some of the criteria options that might be considered in defining "desirable control levels." These sets of goals, then, provide the values to be compared with actual contamination levels for environmental assessment purposes. Work to date has been performed by the Research Triangle Institute on EPA contract 68-02-2612.

The first year of MEG's development was devoted largely to selecting the options to be used as MEG's criteria and investigating ways to approach the problem of defining MEG's for a multiplicity of chemical substances. Initially, the objective of this work was to describe MEG's for chemical pollutants associated with coal conversion processes. However, the value of an expanded list of contaminants was recognized, and the potential for extended application of a MEG's methodology called for the development of a broad, systematic, and adaptable approach for addressing a much larger number of chemical and nonchemical pollutants. Hence the scope of the MEG's program has been expanded to encompass a broad range of objectives which include:

1. Compiling a Master List of all chemical contaminants, complex effluents/mixtures, and nonchemical degradents (such as visual effects, subsidence, heat, and noise) to be addressed by MEG's. (The list is to include but should not be limited exclusively to contaminants from fossil fuels processes.) At present more than 600 chemical substances and physical agents have been listed for consideration.
2. Arrangement of the chemical substances appearing on the Master List into a practical catalog to provide a useful tool for environmental assessment.
3. Design of a format conducive to the concurrent presentation of sets of Emission Level Goals and Ambient Level Goals. (The format should allow ready comparison of the MEG's within a set as well as facilitating comparison of different substances.)
4. Determination of the kinds of data pertinent to desirable control levels and the availability of that data. A format for presenting background information should be established to accompany MEG's specified for each chemical substance.
5. Development of a methodology to establish meaningful values to serve as MEG's for each chemical substance on the Master List. (The methodology should incorporate as MEG's those Federal standards, criteria, and recommendations pertinent to chemical substances.)
6. Presentation, according to the format prescribed, of a set of Emission Level Goals and Ambient Level Goals for each chemical substance appearing on the Master List. (These

MEG's should be accompanied by qualitative supporting data.)

The central purpose of the project remains the derivation of Multimedia Environmental Goals as estimates of desirable levels of control for those chemical contaminants and nonchemical degradents included in a master list.

J. ENERGY AND ECONOMIC FACTORS

Table D12 in Appendix D lists some of the recent projects funded by EPA, EPRI, and others to study energy and economic factors associated with control processes for conventional combustion sources. This is actually only a small fraction of the effort in this category since many of the projects dealing with controls, which are discussed below in Section VII, will deal with economic and/or energy factors during the course of their analysis. Also, many of the general, or integrated, assessments address both energy and economic factors.

K. GENERAL ASSESSMENTS

Argonne National Laboratory (ERDA) began a major program in March 1976 to assess the environmental protection issues associated with electric power generation from coal. The program reportedly has a budget of $1 million per year. The program objection is to produce a continuing series of engineering reports evaluating the performance, costs, and availability of technologies for abating the environmental impacts of coal-to-electricity processes.

Direct impacts being studied include: those resulting from atmospheric emissions such as particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and trace elements; pollutants in process waste water such as polyaromatic hydrocarbons and trace metals; ground water contamination by the infiltration of pollutants from landfill burial of waste ash, coal fines, and scrubber sludge.

The control technologies are evaluated within the context of existing and anticipated emission regulations for coal-fired plants and current understanding of the health and ecological effects of coal combustion pollutants.

The assessments will consider the availability dates of various technologies, capital and operating costs, operating reliability, adaptability of existing facilities to retrofitted control systems, the potential for improved pollution control, the availability of needed hardware, manpower, materials, transportation facilities, and site specific factors.

Projects are being carried out by a number of contractors to meet the program goals. All of the projects are limited to literature assessments. The average project size is $40,000-$90,000/year. Contractors include: Bechtel--coal cleaning; TVA--scrubbers; Southern Research Institute--particulates; KVB--burner design for NO_x control; Foster/Wheeler--gasification/ combined cycle.

Technekron is carrying out a program titled "An Integrated Technology Assessment of Electric Utility Energy Systems." The program period is from 7/1/75 to 12/31/78. Total funding is reported as being approximately $2.0 million (OEMI, EPA). The best program description we have at present is the following one by Technekron to ERDA.

(1) To assist the Environmental Protection Agency in developing environmental control policies and implementation strategies for mitigating the adverse impacts of various electrical generating technologies; (2) to assist EPA's Office of Research and Development in evaluating the portion of its environmental research program dealing with the problems of electrical generating technologies.

Annual technology assessments are made of the electrical utility sector (conventional coal combustion, flue gas cleaning, fluid bed combustion, low-Btu gasification, sulfates, thermal control, waste as fuel, nuclear and geothermal), paying particular attention to the residuals resulting from alternative facility siting options and emission control levels, and to the effects of these residuals upon the human and natural environment.

The above two major programs should be more thoroughly investigated and carefully followed by the CCEA program. Consideration should given to overall coordination and technology exchange.

VII. CURRENT STUDIES RELATED TO CONTROL TECHNOLOGY

A. INTRODUCTION

The control of pollutant emissions has been the foremost research task of EPA's Industrial Environmental Research Laboratory (IERL) since its inception. Emphasis in this research has been primarily on SO_2, NO_x, and particle controls. Although it has long been recognized that thermal pollution can have adverse effects on aquatic ecosystems, precedence has been given to the criteria pollutants that are well known as detrimental to human health.

Although only recently founded, the Electric Power Research Institute (EPRI) has also vigorously moved into research on control of SO_2, NO_x, and particle emissions from utility plants. In 1977 it budgeted over $16 million for air quality control, water quality control, and heat rejection. Although this figure will be reduced to about $13 or $14 million per year for the 1978-1981 period, it still represents a very significant research thrust and is evidence of the utility industry's determination to develop the control measures necessary to meet Federal and State air and water quality standards.

All funding given below is on a fiscal year basis unless otherwise noted.

B. SO_2 CONTROL

Flue gas desulfurization is a mature technology, with approximately 23,500 MW of "first generation" controlled units in operation or under construction and approximately 30,000 MW in the planning stage. Second generation technology is moving into the demonstration-commercialization stage. Industry is assuming an increasing share of the burden in testing, which has been reflected by a drop in the IERL budget for FGD work from approximately $9 million budgeted in FY1976 to $4.6 million budgeted in FY1977. IERL/RTP and EPRI are preeminent in the field of FGD development technology. Table D13 in Appendix D lists many of the research projects. A brief description of some of the most significant projects is presented below.

1. IERL/RTP Projects

Bechtel Corporation--Shawnee Prototype Study of Lime/Limestone Scrubbing-Advanced Testing and Data Evaluation (EPA, $799K)

Project description: Based on testing which was almost continuous from 1972 on at Shawnee, Bechtel is conducting an advanced test program to supply information and optimize lime and limestone scrubbing systems in the areas of improved sludge disposal properties, improved system control and reliability, variable load operation, and improved process economics. The present program will cover at least 3 years. Advanced scrubbing concepts which have shown promise during tests at IERL/RTP's Research Triangle Park pilot plant will be studied on a larger scale. Both high alkali utilization and high oxidation of sulfite to sulfate is being obtained now. This would favorably affect both the economics and the quantity and quality of sludge produced. Accumulation of mud-type solids is drastically reduced with high alkali utilization eliminating many of the persistent reliability problems, especially in the mist eliminator area.

Louisville Gas and Electric--Full-Scale Utility Double Alkali Demonstration

Project description: This project is a full-scale demonstration (278 MW) of the double alkali flue gas desulfurization process in pulverized-soft-coal-fired utility boilers. The objective is to evaluate the effectiveness of the removal of SO_2, organic material, and particulates. Operational parameters will be varied to optimize effectiveness. Soluble materials produced by the process will be evaluated for possible leaching potential from solid waste materials disposed of in landfill. Entire cost of installation, $16,300,000, is being borne by LG&E. However, performance testing and a year's operational study is being funded by IERL/RTP at $4,500,000. The EPA support contractor is Bechtel Corporation. SO_2 removal efficiencies of greater than 95 percent are guaranteed by the vendor, Combustion Equipment Associates. Restricted use of soda ash to 0.045 moles/mole of sulfur removed is required.

Tennessee Valley Authority--Lime/Limestone and Advanced Concepts; TVA's 1-MW Pilot Plant ($450K)

Project description: The objective is to develop reliable closed loop mist eliminator systems for lime/limestone systems now in operation or planned in the near future and also, to develop, to the extent possible, less costly advanced systems.

Aerospace--Study of Disposal of Byproducts from Non-Regenerable FGD Systems ($363K)

Project description: The project will compare chemical and physical characteristics of the waste with current, proposed, or potentially applicable environmental standards; assess feasibility, performance, and costs of proposed methods by measuring physical/chemical properties of waste; provide engineering/analytic support for a field disposal operation at TVA's Shawnee plant; evaluate other field data, and conduct engineering cost studies; make recommendations regarding alternate disposal approaches; and assemble, assess, and report on an annual basis all EPA, TVA, and private industry R&D in the FGD waste area.

Tennessee Valley Authority--Processing Sludges from Lime/Limestone Wet Scrubbing, etc. ($375K to date)

Project description: This project is a pilot scale evaluation of sludges from lime/limestone flue gas desulfurization processes in terms of physical characterization of sludge solids for ease of dewatering, utilization of the sludge as a fertilizer for its sulfur and filler value, and growth on sludge piles for site reclamation potential.

A. D. Little--Evaluation of Alternatives for Disposal of FGD Sludges ($599K)

Project description: This project evaluates coal mine and ocean disposal of sludge from lime/limestone and dual alkali FGD processes. The full-scale mine disposal is evaluated in terms of potential health effects from ground and surface pollution from the site and for SO_2 emissions from the site. The pilot scale ocean disposal is evaluated in terms of ecological effects on fin and shell fish. This project could just as well have been considered either under the health effects or ecological effects sections.

Northern Indiana Public Service Company (NIPSCO)--Sodium Sulfite/Bisulfite Scrubbing with Thermal Regeneration (Wellman-Lord/Allied Chemical) (IERL/RTP, $8 million; NIPSCO, $8 million)

Project description: In the Wellman-Lord process, SO_2 is absorbed in a sodium sulfite solution to yield sodium bisulfite. Upon heating, the sodium bisulfite regenerates sodium sulfite and releases a concentrated stream of SO_2. The Allied Chemical SO_2 reduction process uses natural gas as a reductant in a proprietary catalytic reactor system producing elemental sulfur. The demonstration system has been retrofitted to a 115-MW coal-fired boiler. The plant acceptance test was successfully completed on September 14, 1977. The plant is presently beginning a 1-year demonstration test period during which information will be collected and reported regarding pollution control performance, secondary effects, economics, and reliability of the system.

Empire State Electric Energy Research Corporation, Atomic International Division of Rockwell International--Advanced Regenerable FGD Demonstration (Aqueous Carbonate Process)

Project description: In the aqueous carbonate process, sodium carbonate is contacted with the flue gas in a spray dryer to yield sodium sulfite as a dry powder which is collected and regenerated. The sodium sulfite is fed, along with carbon (either coal or coke), to a molten salt bath. The sulfite is reduced to sulfide; carbon is oxidized to carbon dioxide. The sodium sulfide is then dissolved in water and the solution filtered to remove ash. The clarified solution is contacted with the carbon dioxide-rich off gas from the reduction step to regenerate sodium carbonate and evolve hydrogen sulfide. The hydrogen sulfide is fed to a Claus plant where elemental sulfur is produced. IERL/RTP and Empire State Electric Energy Research Corporation are jointly funding a demonstration of the Atomic International sulfur-producing aqueous carbonate process. The project cost is estimated at $22 million with the IERL/RTP share being $8 million. Design and cost estimates were completed on May 20, 1977. Construction completion and the acceptance test are expected in late 1979 following which a 1-year test and evaluation program will be initiated.

U.S. Bureau of Mines--Demonstration of the Citrate Process FGD System

Project description: IERL/RTP and the U.S. Bureau of Mines have entered into a cooperative agreement to pool funds and technical talent to demonstrate the citrate process, which has been developed through pilot scale by the Bureau of Mines. Together they have initiated the demonstration on a 53-MW coal-fired boiler. A contract between U.S. Bureau of Mines and St. Joe Minerals was signed in June 1976 and initial design and cost estimation was completed in November 1976. The Morrison-Knudsen Company has been awarded a "turnkey" design/build/operate contract for the project. In this process an aqueous solution of sodium sulfite, sodium bisulfite, sodium thiosulfate, and other sulfur compounds absorbs SO_2. The solution is buffered with citric acid to maintain pH at an optimum level for high-efficiency scrubbing and high-SO_2 loading capacity. It is then fed to reactors where gaseous H_2S is added. Net reaction is the combining of SO_2 and H_2S to form elemental sulfur, which precipitates and is separated by flotation.

2. EPRI Projects

Battelle Columbus--RP209

Project description: EPRI's Air Quality Control Program has funded a number of projects that will provide a firm data base for lime/limestone scrubber design. In this project, Battelle Columbus evaluated the scrubbing installations across the United States, summarized the state-of-the-art of lime/limstone scrubbing technology, and highlighted the number of major generic problems that restricted the performance reliability and cost of this technology. The approach has been to focus on each of the subsystems that make up a scrubber. These subsystems, which include reheaters, demisters, contactor absorbers, recycle tanks, and dewatering devices, must be designed to insure their individual reliability and thus the reliability of the entire scrubber system. In an initial report, available from EPRI, Battelle evaluated 15 parameters that must be considered in designing a reliable and efficient mist eliminator. It also summarized the operational experiences with mist eliminators of all the scrubber systems presently operating in the United States. In a second unit's study recently completed, guidelines are given on how to select the most efficient (energy input) reheater system for reheating a stack gas. As a final result of the Battelle project, a continuing stack gas emission coordination center was established. The center supplies information on currently operating SO_2 cleanup systems with the data base continually updated by visits to utilities, hardware vendors, and technology developers. A computer information storage and retrieval system is maintained using this data base.

Tennessee Valley Authority--Development of Improved Lime/Limestone Scrubbing Technology

Project description: This project made use of the TVA 1-MW pilot FGD plant. The project: (a) studied reheaters as a function of both technical and economic performance to establish a design basis; (b) evaluated the corrosion/erosion resistance of critical scrubber system components as a function of material design and selection; (c) fabricated, operated, and evaluated new lime/limestone scrubber modes including the horizontal and cocurrent scrubbers; and (d) established the relationship between the physical and chemical characteristics of scrubber sludge and full-scale scrubber and boiler operation and characterized scrubber sludge from five operating scrubbers.

Southern California Edison and Stearns-Roger--Evaluation of Improved Process Control Capability for Flue Gas Desulfurization Processes

Project description: The objective is to define the best process control methods for lime/limestone scrubbing, from both the standpoint of control design and instrumentation dependability. The project seeks to define and quantify the factors influencing the performance and reliability of chemistry process control for lime/limestone scrubbing and define the state-of-the-art in flue gas desulfurization chemistry process control in terms of these factors.

Arthur D. Little--Characterization of Low Sulfur/Alkaline Ash Western Coal for Flue Gas Desulfurization Processes

Project description: The study has confirmed that simple chemical analysis of a fly ash by titration with an acid does not totally describe how a specific fly ash will react in a scrubber. A need is indicated to develop a highly reliable, accurate, and consistent reactivity test to measure the available alkalinity in a fly ash. The test could then be universally applied to develop confident designs for scrubbers planning to use fly ash as a scrubbing agent and could minimize piloting efforts to screen a large number of fly ashes for possible use.

Radian Corporation, Michael Baker, Jr.--Byproducts/Waste Disposal for Flue Gas Cleaning Processes

Project description: The objective is to provide the utility industry with a sound data base to permit confident selection of the methods commercially available for disposal of flue gas cleaning waste products. The following tasks are being carried out to: (a) review and assess the existing data base regarding flue gas cleaning wastes; (b) prepare a test program to quantify the variables that affect the physical and chemical stability of scrubber sludge; (c) document the state-of-the-art of sludge fixation and determine its practical significance to the utility industry; and (d) develop a set of sludge disposal guidelines structured in such a manner as to be a useful tool for evaluating alternative approaches and making practical planning decisions.

Envirotech--Sludge Dewatering Equipment

Project description: The objective is to evaluate and define numerous techniques available for sludge dewatering. Envirotech is concentrating on evaluating various bench scale and pilot dewatering devices such as centrifuges, filters, and clarifiers. They also are trying to determine what variables in the sludge affect and determine design of dewatering devices.

RFP--Study of Alkali Scrubbing Chemistry

Project description: This project will attempt to quantify the chemical phenomena of lime/limestone slurry scrubbing processes. The objective is to develop integrated models and correlations of the chemical behavior of lime/limestone scrubbing systems. With these models it is hoped to optimize design and operating variables such as the number of scrubber stages, L/G, limestone utilization, and hold tank residence time with respect to the type of scrubbing contactor used. These models will make it possible to provide reliable design without large, costly safety factors in equipment size, expected performance, and high reagent use. Also, using new data, the result will be potential process improvements involving the use of additives, modified hold tank configurations, modified scrubber vessel design, and/or intentional oxidation.

Tennessee Valley Authority--Advanced Flue Gas Desulfurization Development and Test Facility.

Project description: This project allows continued operation of TVA's Shawnee Test Facility in Paducah, Kentucky. Test modules of 310 MW have been operated since 1971 at Shawnee under sole EPA sponsorship. EPRI will take over some funding and testing of new equipment at the site beginning in 1978. The EPRI project is initially directed at (a) designing and constructing a 10-MW flexible concurrent/countercurrent spray scrubber module, and (b) modifying the TVA scrubber system to operate in a limestone regenerable double alkali mode. EPRI will direct the project in consultation with the established utility Shawnee advisory committee. EPRI welcomes EPA participation on this committee. This is an opportunity for the EPA program to promote increased coordination with EPRI for overall planning purposes. Such an effort is badly needed throughout all the areas of CPA.

Southern Company Services--Evaluation of Three Prototype Flue Gas Desulfurization Processes

Project description: 320-MW advanced FGD systems were tested at the Scholz Plant of Gulf Power. The Chiyoda 101 system scrubs with dilute sulfuric and externally reacts as with limestone to produce commercial gypsum. While the system was plagued with many mechanical problems, the overall process performance was excellent. Process limitations of large equipment size, high L/G, high auxiliary power, and stainless steel construction may be overcome in the Chiyoda 121 process, which is being considered for follow-on work at Scholz. The Combustion Equipment Associates/Arthur D. Little process is a sodium-based concentrated mode dual alkali system with lime regeneration and sulfite-sulfate sludge production. The most important limits are its requirement of lime and makeup sodium and the sludge character with sodium and sulfite leaching potential. Overall system performance was excellent and follow-on work at Scholz involving limestone rather than lime for regeneration is also under consideration. The Bergbau Forschung/Foster Wheeler resox process absorbs SO_2 and promotes oxidation to sulfuric acid on char pellets, uses hot sand and a fluid bed to reconvert to a concentrated SO_2 stream, and then reacts the SO_2 with coal in the resox generator to form elemental sulfur. The mechanical design at Scholz is complex and differs from the German configuration. This U.S. design would require major modification in order to achieve operational success.

Foster Wheeler Energy Corporation--Regenerable Flue Gas Desulfurization-Resox

Project description: EPRI has authorized the design, construction, operation and testing of a 42-MW size resox unit at the Lünan, West Germany, plant of Steag A.G. This resox unit will react concentrated SO_2 with coal to form sulfur. The plant has an operating Bergbau-Forschung unit and gas-blending facility that can simulate alternate process "front-end" streams of rich SO_2. EPRI will receive detailed information on the operating BF unit. Advantages of this project include: (a) completion of 1 year's testing by mid-1979, and (b) operation of the resox on an operating coal-fired boiler FGD process front end.

Atomics International--Aqueous Carbonate Flue Gas Desulfurization Process Development

Project description: This project supports the EPA-Empire State Aqueous Carbonate Process Demonstration plant at Niagara-Mohawk, which has been discussed above. The support project will test tapping and quench, solution chemistry and ash dissolution/reprecipitation, and component corrosion. The questions to be addressed are the system's ability to handle coal, the tapping, quenching, and dissolution of a salt/ash melt, and the ability to operate liquid chemical loops that contain silicon and iron compounds and precipitate ash out of solution.

KVB--Laboratory Evaluation of Dry Alkali or Dry SO_2 Removal

Project description: This project will obtain well characterized data that will define the dependence of the dry alkali SO_2 removal process on various system parameters. These parameters will include several sorbants, temperature-time history, amount of SO_2 removed in suspension versus removal on baghouse filter cake, effect of stoichiometric ratio and any byproduct emissions. The results will help define the larger-scale test now contemplated for the EPRI Arapahoe particulate test facility in Denver, Colorado.

C. NO_x CONTROL

IERL has long recognized that control of stationary source nitrogen oxide emissions represents a unique challenge. NO_x emissions are not restricted to a single class of equipment, nor to a limited range of fuel types, but instead are a natural consequence of any combustion. Although on a mass emission basis utility boilers represent the major source of stationary NO_x, by no means can other source types be ignored. Fuels being utilized range from natural gas through residual oil to coal. After careful consideration of alternatives, it appeared that combustion modification offered the most cost-effective means of achieving NO_x control for stationary sources. The uniqueness of the NO_x challenge was that a control technology development program could not concentrate on a single mode of control such as flue gas scrubbing, but instead had to address combustion in general. Historically, IERL has mounted a multifaceted effort in NO_x control that has involved field studies on existing and modified equipment, fuels research, and fundamental combustion research.

Recently, EPRI has joined EPA in sponsoring NO_x control research activities. Current and planned programs consider both combustor design and post-combustion treatment for utility boilers and gas turbines.

Table D14 of Appendix D lists many of the recent and current EPA and EPRI projects for research in NO_x control technology.

1. EPA Projects

Acurex/Aerotherm--Environmental Assessment of Stationary Source NO_x Combustion Modification Technology

Project description: The emissions assessment portion of this major program has been described in Section VI. However, the project is an overall environmental assessment, the only one of its scope we have seen. The program seeks to quantify the near-source impacts on human health as well as terrestrial and aquatic ecology from the change in gaseous, liquid, and solid emissions resulting from the use of NO_x controls. The overall results are rankings of source/control combinations, now and in the future, based on the potential impacts associated with the use of NO_x combustion modification techniques. A systems analysis effort evaluates the priorities and required schedule for NO_x control development based on current and projected control requirements on a regional and national basis. The effort uses air quality projection models for several NO_x critical regions. These models, together with the source-specific impact data from the process engineering task, suggest the most cost-effective and environmentally sound mix of stationary control techniques for given constraints on source growth, ambient air quality goals, and mobile source standards. The control methods being assessed are low excess air, staged combustion, flue gas recirculation, reduced air preheat, reduced load, water injection, and ammonia injection.

Exxon, Field Testing--Application of Combustion Modification to Power Generating Sources.

Project description: This large project has also been discussed in Section VI regarding emission characterization. The program is measuring the effect of the following combustion modifications: (a) low excess air, (b) staged combustion (over fire air, off stoichiometric combustion), (c) water injection, and (d) load reduction.

KVB--Application of Combustion Modifications to Industrial Combustion Equipment ($798K)

Project description: This large project assessed the effect of combustion modifications on 22 burners in 16 facilities. The combustion types included industrial boilers, gas turbines, internal combustion engines, metal furnaces, mineral kilns, and refinery heaters. Table VIIC-1 summarizes the combustion units studied, the combustion modifications applied, and the results obtained in terms of reduction of NO_x.

KVB, Field Testing--Application of Combustion Modification to Control Pollutant Emissions from Industrial Boilers.

Project description: The use of combustion modification in reducing NO_x emissions from industrial boilers ranging from 3-MW to 147-MW heat input has been investigated during a recently completed field test program. The gaseous and particulate emissions from coal, oil, and natural gas fuels were measured both before and after the combustion modification. Data were taken on particulate size as well as concentration. Trace species and organics emissions were measured on selected units. The principle combustion modification methods that were investigated were low excess combustion air, staged combustion, recirculated flue gas, tune burners, and reset burner registers. Staging was implemented by the use of over fire air ports or by turning off the fuel to some burners and increasing the fuel to others, thus creating zones of fuel-rich combustion. All of the combustion modification methods were effective to varying degrees in reducing the nitrogen oxide emissions and reductions of as much as 50 percent were obtained with several of the modifications.

Aerotherm--Investigation of Staging Parameter for NO_x Control in Both Wall and Tangentially Coal-Fired Boilers

Project description: Tests on an EPA 1.5 x 10^6 Btu/h pilot scale pulverized coal furnace showed that NO_x emissions of 100 to 150 ppm were achievable with the use of two-stage combustion, corresponding to an 80 to 85 percent reduction. Comparable NO_x emission levels were obtained with three different coal types (Montana, Pittsburgh No. 8, Western Kentucky) fired in either a single-wall or tangential configuration. The combustion conditions leading to minimum NO_x appear to be (a) operation of the primary flame zone at 75 to 85 percent of stoichiometric air, (b) complete separation of stage air from the first stage, (c) first stage mean residence time of 3 to 5 s, (d) high first

TABLE VIIC-1. KVB INDUSTRIAL COMBUSTION TEST UNITS SELECTED AND SUMMARY OF RESULTS OBTAINED

Device type	Test site no.	Fuel	Average baseline NO_x ng/J*	Average baseline NO_x ppm @ 3% O_2	Maximum percent reduction in NO_x	Combustion modification†
Natural draft process heater	4	Ref. gas	59	116	18	4/32 BOOS
Natural draft process heater	5/1	Ref. gas	50	97	22	Air register adjust
Natural draft process heater	5/2	Ref. gas	39	76	21	High load, low O_2
Natural draft process heater	7/1	Ref. gas	52	103	8	2/16 BOOS
Natural draft process heater	7/2	Ref. gas	49	98	24	Air register adjust
[illegible] ater, [illegible] at	12/1	Ref. gas	163	320	0	Baseline lowest O_2
	12/1	No. 6 oil	113	222	0	Low O_2 No effect
Forced draft heater	12/2	Ref. gas	109	214	67	Low O_2
	12/2	No. 6 oil	88	157	8	Low O_2
Clay tunnel kiln	1	Nat. gas	46	90	41	Low O_2
Rotary cement kiln (dry process)	3	Nat. gas NG + coke	1,425	2,300	50	Fuel switch, gas to coke
Rotary cement kiln (wet process)	9	Nat. gas	1,319	2,250	14	Low O_2, high air temp.

*$lb/10^6$ Btu = 430 ng/J.

†BOOS = Burners out of service.

TABLE VIIC-1. (con.)

Device type	Test site no.	Fuel	Average baseline NO_x ng/J*	 ppm @ 3% O_2	Maximum percent reduction in NO_x	Combustion modification†
Steel open hearth furnace	14	NG + No. 6 oil	1,094	2,070 (avg)	40	Low O_2
Steel reheat furnace	16/1	Nat. gas	56	110	43	3/27 BOOS
Steel soaking pit	16/2	Nat. gas	52	101	69	Low O_2
Aluminum melter	6	Nat. gas	49	96	0	Low O_2 (NO_x increased)
	6	No. 2 oil	104	185	0	Low O_2 (NO_x increased)
Black liquor recovery boiler	10/2	Liquor	--	52	30	Secondary air adjust
Wood bark boiler	10/1	Wood + NG	124	229	40	Low O_2
Wood bark boiler	13	Wood + coal	188	300	15	Low O_2
CO boiler	11	CO gas	65	126	8	Low O_2
Natural gas engine	2	Nat. gas	1,020	1,990	20	Fuel, air adjust
Diesel engine	15	No. 2 oil	830	1,476	7	Low inlet air temp.
Gas turbine combined cycle	7/3	Ref. gas	59	118	14	1/8 BOOS
Gas turbine combined cycle	8	Ref. gas	52	103	38	4/16 BOOS

stage volumetric heat release rate, and/or (e) first stage combustion preheat. The first stage stoichiometry was the most significant variable in NO_x reduction.

EPA--State of Flue Gas Treatment Technology for Control of NO_x and Simultaneous Control of SO_x and NO_x.

Project description: Flue gas treatment technology attempts to remove NO_x from the gaseous products of combustion. Flue gas treatment techniques include dry selective catalytic reduction processes and wet scrubbing processes. Technology should be able to reduce NO_x emissions by 90 percent and has the potential for 90 percent control of both NO_x and SO_x emissions. NO_x flue gas treatment research and development programs have received a relatively low level of funding since it has not been determined conclusively that high NO_x removal efficiencies will be required. Japanese technology has progressed to the point of being commercially applied to gas- and oil-fired sources. They are also developing sources for application to flue gas from coal-fired sources. EPA is investigating the Japanese and other worldwide technology for potential application to the U.S. coal-fired situation to save both development time and money.

EPA--Evaluation of a Prototype Surface Combustion Furnace

Project description: The emissions characteristics of a prototype surface combustion residential furnace have been evaluated using both propane and natural gas. The pollutants measured were NO_x by chemiluminescence, NO by long path nondispersive infrared, CO and CO_2 by NDIR, and hydrocarbons by flame ionization detector. The combustion of premixed fuel and air takes place on a refractory surface without a visible flame. Heat is transferred from the surface to an air-cooled fire box wall by radiation. This maintains a relatively low surface temperature and reduces the oxides of nitrogen. The furnace was operated over a range of excess air from 5 to 45 percent and with heat input from 16,000 to 24,000 W. For a nominal operating point for natural gas at 10 percent excess air, NO_x emissions were less than 15 ppm. CO and hydrocarbon emissions were also low. Furnace efficiency was greater than 80 percent. Performance on propane was similar.

Exxon--Non-Catalytic Reduction of NO_x with NH_3

Project description: Exxon Research and Engineering Company has developed a postflame injection process for the reduction of NO_x to nitrogen with ammonia. The feasibility of this technique has been demonstrated for an oil-fired boiler by Exxon and Exxon's Japanese affiliate. The technology has been commercialized for oil-and gas-fired boilers. The ammonia injection technology (thermal denox process) is viewed as potentially a useful supplement to available combustion modification techniques for obtaining low NO_x levels for installations that require such degree of control.

A contract has recently been negotiated between Exxon and EPA to explore the application of the technique to coal-fired boilers. The following tasks will be carried out.

a. An analysis of utility boiler types will be made to determine what coal-fired boiler types by design, size, or manufacturer are most likely to be amenable to the thermal denox process.

b. Budget-type cost analysis for the application of the thermal denox process will be made as a function of utility boiler size, fuel, appropriate boiler characteristics, and degree of NO_x reduction.

c. The thermal denox process will be compared with those for extreme combustion modification that would be required to achieve very low NO_x levels.

Monsanto Research--Cyclone Boilers - Their NO_x Emissions and Population

Project description: This project is a paper study. Since cyclonic combustion takes place at high combustion temperatures, cyclone furnaces firing utility and industrial boilers are high NO_x emitters. For this reason, since 1973, the Babcock and Wilcox Company, the major supplier, has not sold a single cyclone unit. However, there are still 149 in existence. Successful operation of the cyclone furnace depends on maintaining a liquid or wet slag within the cylindrical furnace. Fresh coal is introduced tangentially through a primary burner at the front of the cyclone furnace, thrown to the walls of the cyclone, and caught in the running slag. Tangentially supplied secondary air sweeps past the imbedded coal particles, quickly oxidizing them. The cyclone is operated at temperatures as high as 1,920 K. Large quantities of fuel are combusted within a relatively small volume, resulting in furnace high heat release rates. Several combustion modification techniques have been applied to cyclone boilers in an attempt to lower their NO_x emissions. These methods include boiler load restriction, low excess air firing, two-stage firing, and switching fuels. Even though significant reductions in NO_x were achieved, none of the presently known techniques are able to reduce NO_x emissions to the level meeting the EPA's new source performance standards for NO_x.

Combustion Engineering--Over Fire Air Technology for Tangentially Fired Utility Boilers Burning Western U.S. Coal

Project description: The program was conducted on two steam generating units designed with over fire air registers, the first unit firing a western U.S. subbituminous coal and the second firing a western U.S. bituminous coal. The test program evaluated baseline, biased firing, and over fire air operations and consisted of approximately 60 steady state tests per unit. The effect of NO_x control methods on gaseous constituents was evaluated during all tests. NO_x, SO_x, CO, total hydrocarbons, O_2, and particulate samples were measured. In an earlier project, Combustion Engineering evaluated a unit equipped with an over fire air system that was retrofitted. The tests on this unit were made using eastern coal and midwestern coal. The test programs showed that over fire air operation is effective in reducing NO_x emission levels. This can be done without adversely affecting unit performance. Unit loading was found to have a minimal effect on NO_x formation.

EPA--Combustion Control Technology for Conventional Combustion Systems ($60K)

Project description: The objective of the project is to develop technically and commercially feasible combustion control technologies for application to package boilers and other area sources. The study provides for evaluation of emissions and performance of new modified and prototype burners fired with liquid or gaseous fuels. In general, burners having potential for low emissions and high efficiency will be characterized. When possible, modifications will be made to further improve emissions performance and efficiency.

Ultrasystems--Fundamental Combustion Research Applied to Pollution Control

Project description: Because of staff limitations IERL has decided to retain a single contractor to manage and coordinate most of its fundamental research in combustion. This major program of 70,000 manhours over a 3-year period is funded at almost $3.3 million.

The majority of the effort expended under this contract to date has centered around detailed planning of the program and in preparation of work scopes for upcoming subcontracts. After careful review of the various options, EPA and EER have decided to place the primary emphasis on the 3- to 5-year time scale and to conduct the program in such a way that limited payoffs from fundamental combustion research investments are received in short order. It is believed that a significant body of information on the mechanisms controlling NO_x formation currently exists and that careful analysis of that data will yield results of immediate use to Fuels R&D and perhaps the Process R&D programs. Such analysis of existing data is also important in scoping the various programs that will eventually constitute the FCR program.

United Technologies--Advanced Combustion Systems for Stationary Gas Turbine Engines (SGTE)

Project description: In December 1975, a contract was initiated to develop low NO_x combustor technology for stationary gas turbine engines (SGTE). Though SGTE's represent a small percentage of the annual NO_x emissions in the United States (4 percent of the total from stationary sources), the projected growth patterns, fuel utilization trends, and the emergence of high efficiency combined cycles place SGTE's as a high priority source. Without a concerted effort to develop control technology, these projections indicate that NO_x emission factors from new SGTE's may increase by more than a factor of five in the next decade.

Previous research, which was directed toward boiler applications, has shown that modification to the combustion process can significantly reduce NO_x emissions. Though a boiler operates on a different thermodynamic cycle than the SGTE, the mechanisms controlling NO_x formation are quite similar. In formulating the contract program to develop NO_x SGTE combustor technology, maximum use was made of the existing boiler technology.

Current uncontrolled emissions from SGTE's are typically in the 200 to 300 ppm range at 15 percent exhaust O_2 when burning fuels that are free of chemically bound nitrogen. Only limited data are available from units burning fuels with bound nitrogen but those limited data suggest a significant increase in NO_x. The goals of the SGTE program are to develop combustor modification technology, which would result in NO_x emissions below 50 ppm for clean fuels and below 100 ppm for fuels containing up to 0.5 percent bound nitrogen. These goals represent a 75 percent reduction from uncontrolled NO_x emissions.

To achieve these goals a phased program was developed. In the first phase, results from previous control technology development on boilers and

SGTE's were reviewed and a list of candidate combustor design concepts defined. In the second phase, these concepts have been converted to bench scale hardware and are currently being rig tested at conditions that would be expected in an actual engine. In the latter phases, the two most promising combustor designs will be scaled up to the 25 MWe size. These full scale units will be thoroughly rig tested over a range of typical operating conditions and then installed in an actual 25-MW SGTE to verify their low NO_x performance.

At the current time the bench scale testing is nearing completion. A combustion concept producing a fuel-rich primary zone which is then quickly quenched to overall lean conditions has been shown to better the program goals for both clean fuels and fuels with significant bound nitrogen. Efforts are underway to determine how this concept (proven in bench scale equipment) can be scaled up to full size hardware. It is expected that the performance of the full scale hardware will be verified by mid 1978.

2. EPRI Program

The EPRI NO_x Control Program consists of 15 projects and a 6-year budget of $12 million. The program is directed to four objective areas: (a) analysis and control of fuel nitrogen conversions, (b) combustion control for steam generators, (c) combustion control for gas turbine/combined cycle power plants, and (d) postcombustion control of NO_x. Three of the major combustion control projects are summarized below to illustrate some of the scope of the program.

Babcock and Wilcox--Low NO_x Boiler Combustion Process Development Project

Project description: Further reduction of NO_x emissions from the present possible levels of 30 to 50 percent will probably require completely new burner technology that can provide the proper temperature, time, and stoichiometry specifically for low NO_x. The system must physically isolate fuel-rich combustion process from the secondary air injection zone, which is required to maintain an overall oxidizing condition in the boiler. Babcock and Wilcox have proposed the development of a primary combustion furnace concept. Pulverized coal is introduced into a conventional B&W dual-register burner with less air than is required for complete combustion. The extended length of the combustor provides the necessary residence time to partially oxidize the coal and permit the desirable N_2-producing reactions to occur. Heat removal will also occur along the combustion chamber to avoid slagging. Secondary air will be added at the exit of the primary combustion furnace as you bring the combustion products to oxidizing conditions for the balance of their passage through a conventional convector section. The first tests will be at 4×10^6 Btu/h. Heat removal, residence time, and quantity of air in the primary combustion furnace are major parameters to be defined. Then the research will be extended to a 50×10^6 Btu/h facility. This will evaluate material requirements, mechanical design, and longevity as well as confirming the combustion process variables determined in the earlier work. These results can be extrapolated to typical full-scale utility burner ratings ($150\text{-}200 \times 10^6$ Btu/h). Four coal types will be evaluated: two eastern bituminous, one subbituminous, and one lignite.

KVB--Laboratory Evaluation of Coal-Fired NO_x Reduction with Ammonia Injection

Project description: EPRI is continuing to investigate the direct reduction of NO_x with ammonia injection, specifically as it applies to coal combustion, by cofunding a project at KVB with Exxon Research and Engineering Company. Exxon holds a patent on this process. Previous work at KVB established that up to 80 percent NO_x reduction occurs under peak reduction conditions. However, a very narrow temperature window, ± 250° F at 1,750° F, exists. Also, the ratio of injected ammonia to initial nitric oxide is the second critical parameter. Some reductions of up to 92 percent have been obtained at optimum ratio of ammonia and critical peak temperature. The present research is directed at determining the levels of NO_x removal possible for four different coals: (a) New Mexico subbituminous, (b) Pittsburgh seam No. 8 bituminous, (c) Illinois No. 6 bituminous, and (d) Utah low sulfur bituminous. Tests are also being performed to obtain data on the type and concentration potential byproduct emissions, and to determine the extent to which hydrogen can lower the effective process temperature range. The tests will be conducted in the KVB 3×10^6 Btu/h facility.

International Harvester Company--Evaluation of a Pre-mixed, Pre-Vaporized Gas Turbine Combustor

Project description: EPA has issued proposed emission standards of 75 ppm at 15 percent O_2 for industrial gas turbines. The only means currently available for meeting these standards involves water injection into the combustor. Unfortunately this has a high capital cost and necessitates increased fuel consumption. EPRI has undertaken a project to evaluate the feasibility of a low-emission combustor that does not use water or steam. All proposed dry methods require that the fuel and air be completely mixed prior to combustion. In order to obtain the premixing for very low NO_x conditions, higher than usual temperatures of the inlet air, which provides the heat of vaporization of the oil, is required. These conditions frequently occasion auto ignition. Tests will be made in the future to study the effect of increased initial fuel dispersion through more fuel injection sites and droplet size. Considerable additional research will be required before a commercially acceptable solution can be found.

D. PARTICULATE CONTROL TECHNOLOGY

IERL-RTP's program for particulate control is designed to establish engineering design techniques and performance models, and to improve the collectibility and economics of control devices for particulate matter.

Attainment of the present Primary Standard for particulates in some cases will be difficult and expensive with existing technology; attainment of the Secondary Standard (or a more stringent Primary Standard) appears impossible without improved technology. There are two basic causes for this: particulate control technology has limited control capability, in many cases even for coarse particulate; and technical and economic factors often prevent control technology from being feasible in specific industrial applications.

IERL-RTP is placing increased emphasis on the control of fine particulates that persist in the atmosphere, comprise a variety of known toxic substances, and are major contributors to atmospheric haze and visibility problems. The objective is the development and demonstration of control technologies capable of effectively removing large fractions of the under-3-μ size particles from effluents. The technical approach is to identify capabilities of existing equipment (electrostatic precipitators [ESP's], filters, scrubbers, and proprietary devices), to determine deficiencies in present design and operating procedures, and to pursue remedies for the deficiencies in present design and operating procedures, and to pursue remedies for the deficiencies through research and development. New concepts will be applied as discovered, and successful advancements in removal technology will be demonstrated. Results will be applicable to improvements in high-temperature/high-pressure particulate removal devices.

Although the EPRI research program on particulate controls is of more recent vintage than that of EPA, a survey of the projects listed in Table D15 of Appendix D will suffice to show that EPRI regards particle control technology as an area that requires a major thrust. As in the EPA programs, EPRI is considering fabric filtration, hot gas cleanup and electrostatic precipitation with the objectives of demonstrating the capability of eliminating plume opacity and controlling fine particles by 1980.

1. EPA Projects

Southern Research Institute--Electrostatic Precipitators for Control of Fine Particles

Project description: The project consists of eight related tasks with the overall purpose of defining the parameters of the electrostatic particulate collection process to the degree that the precipitator can be effectively modeled utilizing a computer system technique. Two tasks are for a measurement program to define the actual operating conditions of full-scale industrial electrostatic precipitators. The program consists of measuring the fractional and overall collection efficiency of the device, the chemical and physical characteristics of the particulate, and the operating characteristics of the precipitator. These measurements will provide the inputs to the task that are associated with improving existing computer systems models.

Midwest Research Institute--Fine Particle Emissions Information Systems Development

Project description: The fine particle emissions information system is a computerized information system containing data on primary fine particle emissions to the atmosphere from stationary point sources and includes data on applied control devices. The purpose is to provide a centralized source of comprehensive fine particle measurement information. The system contains emission test data from a variety of industrial sources. General categories of information contained in the system include source characteristics; control system description; test characteristics; particulate mass train results; physical, biological, and chemical properties of the particulates; particulate size measurement equipment/method; and particulate size distribution data.

The system has been implemented at the EPA National Computer Center at Research Triangle Park, on the UNIVAC 1110 Computer using system 2000, a flexible data base measurement system. The system presently contains data for more than 1,000 sampling runs. Current estimates indicate there are approximately 4,000 known sampling runs in existence today. Activities now underway will enable the system to contain at least three-fourths of the known data by the end of 1978.

EPA--Demonstration of a High Efficiency/High Throughput Baghouse ($500K)

Project description: The objective is to examine technical and economic aspects of small, full-scale, reverse air baghouses operated at filtration velocities up to 9 ft/min, for stoker-fired industrial boilers. The project will: (a) operate a baghouse for a minimum period of 10 months using Nomex, Gor-tex, Teflon, and Dralon T fabrics; (b) determine fabric performance and life; (c) determine system performance and cost; (d) record all pertinent boiler and filter system operating parameters; and (e) characterize flue gas streams and fly ash. The scheduled start of the project was 12/76. Options include testing additional fabrics and testing SO_2 removal capabilities.

GCA--Fabric Filtration Measuring and Modeling Program ($108K)

Project description: The objective is to characterize the performance of four different industrial fabric filter systems (2 electric utility boilers, an electric arc furnace, and a municipal incinerator) and to use published and laboratory-generated data to develop mathematical models useful for the design of fabric filter systems. Of particular importance is the particulate removal efficiency of baghouses as a function of particle size. The fractional efficiency of fabric filters is determined by sampling with inertial and diffusional sizing technique and the total mass efficiency is determined utilizing simultaneous upstream and downstream method five techniques.

Southern Research Institute--Evaluation of Hot Side Electrostatic Precipitator

Project description: Electrostatic precipitation (ESP) efficiency depends on, among other variables, the resistivity of the fly ash particles being removed from the fine gas stream. Particle resistivity depends upon the types of minerals in the fly ash and upon the temperature of the gas stream. When low-sulfur coals are burned there is difficulty in obtaining a sufficiently low resistivity for efficient particle scrubbing unless other substances, often deliberately added, are present. An alternative method is to operate the ESP with a hot gas stream rather than with a cooled stream. This is a relatively new approach with very little information on the collection efficiency and economics of the process. The objective of this project is to develop such information. Additionally, the project is developing information on the trace element content of the particles captured by the ESP. During 1977, field testing was carried out on a hot side ESP unit installed at the Navajo Station, Page, Arizona. Although these are now complete, work is still being performed on the trace element and economic analyses.

Air Pollution Technology, Inc.--Effects of Conditioning Agents on Emissions from Coal Fired Boilers

Project description: This research is determining the effect of deliberately added compounds, such as SO_3, V_2O_5, and various proprietary mixtures of organic and inorganic species, in improving ESP collection efficiency by reducing particle resistivity or enhancing agglomerating characteristics. In addition to obtaining definitive, quantitative data on the effects of these agents on collection efficiency, measurements are being made to determine the decomposition products of these agents and the amount of such material that may pass through uncollected in order to test the assumption that all such products are collected, or that at least the emitted material has negligible pollution potential.

2. ERDA Projects

ERDA--Electrostatic Precipitation of High Resistivity Fly Ash in Stack Gases ($250K)

Project description: The objective is to improve the design and sizing criteria of electrostatic precipitation for the high resistivity fly ash as produced from low sulfur western coals. The submicron particulates from combustion of lignite containing a high percentage of alkalis will be characterized. The procedures are: (a) fly ash resistivity is measured; (b) collected fly ash is reentrained into flue gas in the laboratory and ESP efficiency is measured with and without additives; (c) a 75 lb/h burner is being designed to generate fly ash under control conditions; (d) a new ESP is being designed and built to measure ESP efficiency under laboratory conditions; (e) field tests will be conducted to relate lab data to ESP efficiency on commercial size units of known design operating on known coal to establish sizing criteria; and (f) collecting and analyzing submicron particulates with the aid of a scanning electron microscope.

3. EPRI Projects

EPRI projects in the particulate control technology program are funded primarily in electrostatic precipitator technology. The largest expenditure, $10.35 million over 1975-1982, is for the fabrication and operation of a pilot plant at Arapahoe Station. Other research is being carried out on the fractional collection efficiency for ESP ($900K), ESP plate rapping and reliability modeling ($265K), and flue gas conditioning to improve collection efficiency ($275K). Also, a high intensity ionizer is being retrofitted on a TVA plant ($585K).

EPRI is also funding fabric filtration development and hot gas cleanup.

E. THERMAL POLLUTION CONTROL

Power plants reject enormous amounts of heat energy that is no longer able to perform useful work in the power production cycle. Current projections indicate that waste heat rejection from central power stations in the year 2000 will nearly equal the total U.S. energy consumption in 1970. Under the provisions of the Federal Water Pollution Control Act Amendments of 1972, EPA is required to regulate thermal effluents. IERL-RTP's research and development program in the thermal control area supports the Agency's statutory requirements and falls primarily into two broad areas: combustion source cooling technology, and waste heat utilization. Programs underway in the former area include analysis of first generation cooling system performance and economics, assessment of advanced heat rejection techniques, and development of control technology for treatment and reuse/recycle of cooling system effluent streams. Waste heat utilization studies presently underway involve primarily agricultural applications. Aquaculture uses may merit future consideration. Some of the major EPA projects are listed in Table D16 of Appendix D.

EPRI is also sponsoring research in this area. As of March 1, 1977, nine projects were underway. Titles are shown in Table VIIE-1. The combined 1977 budget for the EPRI Water Quality Control and Heat Rejection program was $1.89 million.

TABLE VIIE-1. EPRI WATER QUALITY CONTROL AND HEAT REJECTION R&D PROJECTS

(As of March 1, 1977)

Reject Heat Management	
RP256	Chalk Point Cooling Tower Project
RP373	Agricultural Waste Water for Power Plant Cooling
RP422	Power Plant Waste Heat Rejection System Using Dry Cooling Tower
RP732	Modeling and Verification of Near-Field Behavior of Mechanical Draft Cooling Tower Plumes
RP733	Ozone Dosage and Contacting for Condenser Biofouling Control
RP738	Performance Testing and Model Development for Wet/Dry Cooling Towers
RP901	Numerical Modeling Techniques for 3-Dimensional, Recirculating Flows in the Near-Field of Cooling Tower Plumes
RP905	Acceptance Test Methodology for Cooling Towers
RP906	Survey of Models and Data Bases for Cooling Tower Plume Prediction
Water Quality	
RP902	Fundamental Studies of Mechanisms of Biofoulant Film Buildup and Destruction
RP909	Development of Comprehensive Water Management Methodology
RP910	Trace Element Removal by Adsorption on Iron Hydroxides

APPENDIX B

EXISTING AND PROPOSED FEDERAL REGULATIONS FOR CONVENTIONAL COMBUSTION SOURCES

APPENDIX B

EXISTING AND PROPOSED FEDERAL REGULATIONS FOR CONVENTIONAL COMBUSTION SOURCES

Regulatory policy, as it concerns environmental pollutants, is still in its early stages, as can be witnessed by the very great increase in promulgation of regulations in the last 2-1/2 years. For example, during this period, 40 point source categories have been addressed by Effluent Standards, and 24 point source categories have received New Source Performance Standards for emissions to the atmosphere. No Federal regulations for these categories existed before 1973.

The Environmental Protection Agency has taken the lead in the establishment of most environmental regulations, although the Occupational Safety and Health Administration (through utilization of the threshold limit values established by the American Conference of Governmental Industrial Hygienists) has listed comprehensive limitations for contamination of industrial workroom air, and the former Atomic Energy Commission provided regulations for the control of radionuclides.

The terms "standards" and "regulations" are normally intended to mean limitations enforceable by law. "Criteria" are used in evaluating standards but are not legally enforceable.

B.1 Current Regulations

Table 1 lists the most important categories of environmental regulations presently enforceable by Federal law. Table 2 gives a listing of high priority pollutants keyed to the regulation listing of Table 1 [B1]. Regulations are forthcoming, covering some 124 elements and compounds, to be

TABLE 1. FEDERAL REGULATIONS APPLYING QUANTITATIVE LIMITATIONS TO SPECIFIC, POTENTIAL ENVIRONMENTAL POLLUTANTS FROM CONVENTIONAL COMBUSTION SOURCES

a. National Primary and Secondary Ambient Air Quality Standards

b. Occupational Safety and Health Administration Standards for Air Contaminants

c. National Emission Standards for Hazardous Air Pollutants

d. New Stationary Source Performance Standards

e. EPA Effluent Standards

f. EPA Toxic Pollutant Effluent Standards (Proposed)

TABLE 2. HIGH PRIORITY POLLUTANTS WITH ASSOCIATED REGULATIONS[*]

	Regulatory Listing[†]					
Substance	a	b	c	d	e	f
Ammonia		x			x	
Arsenic		x			x	
Asbestos		x	x		x	
Barium		x			x	
Benzidine		x				x[††]
Beryllium		x	x			
Cadmium		x			x	
Carbon Monoxide	x	x		x		
Chlorine, Chloride		x			x	
Chromium		x			x	
Copper		x			x	
Cyanide		x			x	
Fluorides		x		x	x	
Hydrocarbons	x	x		x		
Hydrogen Sulfide, Sulfide		x			x	

[*] All addressed by more than one standard or regulation.

[†] The letters under regulatory listing apply to the listing in Table 1. X indicates that the specific pollutant has been addressed and that further details may be found in Section 3 and/or the Appendices.

[††] Legal establishment pending (see Subsection h; Section 3).

TABLE 2. (Continued)*

Substance	Regulatory Listing⁺ a	b	c	d	e	f
Iron		x			x	
Lead		x			x	
Manganese		x			x	
Mercury		x	x		x	
Nickel		x			x	
Nitrogen Oxides, Nitrate	x	x		x	x	
Oil and/or Grease		x			x	
Osmium		x			x	
Ozone (oxidants)	x	x				
Particulates	x	x		x	x	
Phenol, Phenolic compounds		x			x	
Phosphorus		x			x	
Platinum		x			x	
Radioactive Materials		x			x	
Rhodium		x			x	

TABLE 2. (Continued)*

Substance	Regulatory Listing†					
	a	b	c	d	e	f
Selenium		x			x	
Silver		x			x	
Sulfur Dioxide (also sulfate)	x	x		x	x	
Tin		x			x	
Uranium		x			x	
Water Parameters (BOD, TSS, pH, COD)					x	
Zinc		x			x	

applied to almost 300 point source categories, including SIC-4911 (Steam Electric Power-Plants) over the next two to three years. These will greatly change the scope of (proposed) EPA Toxic Pollutant Effluent Standards, item (g) on Table 1.

The application of the regulations listed in Table 1 to conventional combustion sources will be discussed in the sequence shown in Table 1.

a. National Primary and Secondary Ambient Air Quality Standards

The National Ambient Air Quality Standards are summarized and tabulated in Table 3. All standards are specified as not to be exceeded more than once per year. The measurement methods are also specified as Federal Reference Methods. The air quality standards and a description of the reference methods were published on April 30, 1971 in 42 CFR 410, recodified to 40 CFR 50 on November 25, 1972. Primary standards are set for the protection of health. Secondary standards are set for the protection of Welfare, which, in the words of the Act "includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well being." The Clean Air Act Amendments of 1977 call for the Administrator of EPA to revise and reissue criteria of NO_2 concentrations to be averaged over a period of not less than three hours as he deems appropriate. This revision, to be performed within six months of the effective date of the law, will include nitric and nitrous acids, nitrites, nitrates, nitrosamines and other carcinogenic or potentially carcinogenic oxides of nitrogen.

TABLE 3. NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Particulate matter[*]	Annual (geometric mean)	75 $\mu g/m^3$	60 $\mu g/m^3$
	24-hour	260 $\mu g/m^3$	150 $\mu g/m^3$
Sulfur dioxide	Annual (Arithmetic mean)	80 $\mu g/m^3$ (0.03 ppm)	---
	24-hour	365 $\mu g/m^3$ (0.14 ppm)	---
	3-hour	---	1300 $\mu g/m^3$ (0.5 ppm)
Carbon monoxide	8-hour	10 mg/m^3 (9 ppm)	Same as primary
	1-hour	40 mg/m^3 (35 ppm)	
Photochemical[†] oxidants	1-hour	160 $\mu g/m^3$ (0.08 ppm)	Same as primary
Hydrocarbons[††] (nonmethane)	3-hour (6 to 9 a.m.)	160 $\mu g/m^3$ (0.24 ppm)	Same as primary
Nitrogen Dioxide[**]	Annual (Arithmetic mean)	100 $\mu g/m^3$ (0.05 ppm)	Same as primary

[*] The secondary annual standard (60 $\mu g/m^3$) is a guide to be used in assessing implementation plans to achieve the 24-hour secondary standard.

[†] Expressed as ozone by the Federal Reference Method.

[††] This NAAQS is for use as a guide in revising implementation plans to achieve oxidant standards.

[**] To be reassessed pursuant to the Clean Air Act Amendments of 1977.

Another feature of the Clean Air Amendments of 1977 (Section 127) is the requirement for the EPA Administrator to propose within two years new regulations for hydrocarbons, carbon monoxide, photochemical oxidants and nitrogen oxides in "clean air areas" where significant deterioration must be prevented. Increments and ceilings for particulate matter and sulfur dioxide are specified in areas of various classification in Section 127.

b. Occupational Safety and Health Administration Standards for Air Contaminants

Most of the standards for air contaminants in workroom atmosphere, established by the Occupational Safety and Health Administration (OSHA), are based on the Threshold Limit Values (TLV's) published by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1968. Specific regulations have been established for asbestos and vinyl chloride. The standards for air contaminants including asbestos and vinyl chloride, are set forth in 29 CFR, Part 1910, Subpart G, of the Code of Federal Regulations.

c. National Emissions Standards for Hazardous Air Pollutants

National Emissions Standards for Hazardous Air Pollutants have been established by EPA to limit emissions of certain very hazardous substances from specific source categories. Pollutants addressed by these standards have been shown to cause or contribute to an increase in mortality or to an increase in serious irreversible or incapacitating reversible illness. The first standards, promulgated in Part 61, 40 CFR, pertain to asbestos, beryllium, mercury and vinyl chloride. The emissions standards for mercury and beryllium are derived from ambient concentrations which are considered to be safe, i.e., levels that will not adversely affect human health. Lead and fluorides are under study for National Emissions Standards for Hazardous Air

Pollutants, with the proposed standard for lead scheduled for publication, for public comment, in December 1977.

In addition, Section 122 of the Clean Air Act Amendments of 1977 require the Administrator of EPA to review all relevant information on health effects of cadmium, arsenic and polycyclic organic matter to determine, by September 1978, whether these should be added to the list of regulated, hazardous pollutants or to the list of criteria pollutants. Radionuclides are to be considered by September 1979.

d. New Stationary Source Performance Standards

New Stationary Source Performance Standards (NSPS) have been promulgated for a number of industries. This category of regulation prescribes standards of performance for sources for which construction is commenced after the publication of applicable standards.

The term "standard of performance" means a standard for emissions of air pollutants that reflects the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) EPA determines has been adequately demonstrated. EPA is not attempting to define averages or representative emission rates. Consideration of cost is applied as a modifier to avoid extremes. In the words of the Committee on Public Works, "the technology must be available at a cost and at a time which the Administrator determines to be reasonable."

Individual standards are not intended to be protective of health or welfare effects; that is, they are not designed to achieve any air quality goals. The standards are designed to reflect the best technology for each individual source. The long-range goal and overriding purpose of the collective body of standards is to prevent new pollution problems from developing. To achieve this end, the standards must be an incentive for technological change, and the justification for the standards must allow for technology transfer.

Part 60, 40 CFR, Subparts D and E, which apply NSPS to fossil fuel fired steam generators and to incinerators, respectively, are the regulations having the most impact on conventional combustion sources. These are summarized in Table 4.

e. EPA Effluent Standards

Standards promulgated or proposed under 40 CFR, Parts 402 through 699, prescribe effluent limitations guidelines for existing sources, standards of performance for new sources, and pretreatment standards for new and existing sources. The standards are applicable to particular classes of point sources and pertain to discharges into navigable waters without regard to the quality of the receiving water.

Limitations based upon application of the best practicable control technology currently available (BPT) apply to existing point sources and must be achieved by July 1, 1977. Limitations based upon application of the best available technology economically achievable (BAT) which will result in reasonable further progress toward elimination of discharge must be achieved by July 1, 1983. New Source Performance Standards (NSPS) apply to sources for which construction is commenced after publication of proposed regulations prescribing standards of performance for new sources of a point source category.

TABLE 4. NEW SOURCE PERFORMANCE STANDARDS FOR FOSSIL FUEL FIRED STEAM GENERATORS AND INCINERATORS

New Stationary Sources Performance Standards	Pollutant	No Discharge in Excess of Regulation	Opacity
Subpart D - Fossil Fuel Fired Steam Generators Generating more than 63 million Kcal per hr heat input (250 million Btu/hr)	Particulates	0.18 g/million cal input (0.10 lb/million Btu) derived from fossil fuel	20%
	Sulfur Dioxide	1.4 g/million cal heat input (0.80 lb/million Btu) derived from liquid fossil fuel	20%
		2.2 g/million cal heat input (1.2 lb/million Btu) derived from solid fossil fuel	
(When lignite or a solid fossil fuel containing 25% by wt. or more of coal refuse is burned in combination with other fuels, the standard for nitrogen oxides does not apply.)	Nitrogen Oxides	0.36 g/million cal heat input (0.20 lb/million Btu) derived from gaseous fossil fuel	20%
		1.25 g/million cal heat input (0.70 lb/million Btu) derived from solid fossil fuel (except lignite)	
Subpart E - Incinerators	Particulates	0.18 g/dscm 0.08 gr/dscf/corrected to 12% CO_2	

Tables 5 and 6 show the pollutants and other water quality characteristics addressed by the current effluent standards and Table 7 shows the standards pertaining to steam electric power generation plants. As mentioned previously, new water quality criteria and effluent standards addressing some 124 elements and compounds will be forthcoming over the next two years.

f. EPA Toxic Pollutant Effluent Standards (Proposed)

The first Toxic Pollutant Effluent Standards were to have been promulgated by EPA by February 1977. These standards are to be established for specifically designated toxic substances, and they are set without regard to the quality of the receiving water or the technology applicable to the source of the toxic effluent.

Efforts to promulgate standards under this provision have been underway since 1973, when the initial list of nine toxic pollutants was published in the Federal Register. Significant milestones in these efforts are described below.

1. July 6, 1973 — List of nine toxic pollutants published:

    aldrin/dieldrin
    benzidine
    cadmium
    cyanide
    DDT (DDD, DDE)
    endrin
    mercury
    PCB's
    toxaphene

TABLE 5. POLLUTANTS ADDRESSED BY EFFLUENT STANDARDS

Aluminum
Ammonia
Ammonia (as N)
Arsenic
Asbestos
Barium
Cadmium
Chlorine: (free available)
Chrome
Chromium; total
Chromium; dissolved
Chromium VI
Copper
Copper; dissolved
Cyanide (total)
Cyanide (amenable to chlorination)
Fluorides
Gold
Iridium
Iron
Iron; dissolved
Iron; filtrable
Lead
Manganese
Mercury
Nickel
Nitrate
Nitrate (as N)
Organic Nitrogen (as N)
Osmium
Palladium
Phenol
Phenolic Compounds
Phosphorus
Phosphorus, Elemental
Platinum
Radium 226
Rhodium
Ruthenium
Selenium
Silver
Sulfate
Sulfide
Uranium
Zinc
Zinc; A

TABLE 6. OTHER WATER QUALITY CHARACTERISTICS ADDRESSED BY EFFLUENT STANDARDS

COD
pH
TSS
BOD_5
Oil and grease
Temperature
Fecal coliform
Settleable solids

TABLE 7. EPA EFFLUENT STANDARDS FOR STEAM ELECTRIC POWER GENERATING PLANTS

Category	Subcategory	Basis	Pollutant or effluent characteristic	Maximum for any one day	Average of daily values for 30 consecutive days shall not exceed:
Steam Electric Power Generating (Part 423) [Regulations concentrations expressed in mg/ℓ]	A. Generating Unit	BPT, BAT NSPS	pH, all discharges	6-0-9.0	
			Polychlorinated Biphenyl compounds	No discharge	
			TSS	100	30
			Oil and Grease	20	15
			Total Copper from metal cleaning wastes or boiler blowdown	1.0	1.0
			Free available chlorine from cooling tower blowdown	0.5	0.2
			Materials added for corrosion inhibition in cooling tower blowdown	No detectable amount	

2. December 27, 1973	Proposed toxic pollutant effluent standards published for each of the nine substances on the list.
3. April and May 1974	Hearing was held. Following the hearing, the agency concluded that, because of problems and data gaps, it could not promulgate the proposed standards.

The decision was made to gather additional data and repropose standards, treating the nine substances individually or in small groups.

4. June 10, 1976	Standards proposed for: aldrin/dieldrin DDT (DDD, DDE) endrin toxaphene
5. June 30, 1976	Hearings held regarding proposed standards for: aldrin/dieldrin DDT (DDD, DDE) endrin toxaphene
6. July 12, 1976	Standards proposed for: benzidine
7. July 23, 1976	Standards for polychlorinated biphenyls proposed.

8. July 30, 1976 Hearings held regarding proposed standards for benzidene.

Adopted standards were to be added at 40 CFR, Part 129.

The following substances have also been examined for possible addition to the toxic pollutants list:

arsenic
selenium
chromium
lead
asbestos
sevin
zinc
chlordane
lindane
acridine
hydroquinone
chlorinated hydrocarbons
organophosphates
ortho-chlorophenol
beta-naphthol
alpha-naphthol
beryllium
nickel
antimony
heptachlor
camphor
methyl parathion
parathion
di-n-butyl phthalate
heavy metals

materials listed as carcinogens by the Department of Labor.

With the passage of the Toxic Substances Control Act, a much broader range of materials has been mandated for EPA investigation and possible regulation. This has considerably altered the regulatory approach for toxic substances in effluents and as a result the standards which were to become Part 129, 40 CFR are not yet promulgated.

B.2 Regulations Under Consideration

Possible changes in regulations due to the Clean Air Act Amendments of 1977, and the Toxic Substances Control Act have been cited above in the context of existing or proposed regulations. In addition to these, several other major changes in regulations are being considered. These include:

1. Fuel Analysis Regulations for Existing Fossil Fuel-Fired Steam Generators - establishing procedures for monitoring of SO_2 emissions from these sources by analysis of the fuels burned;
2. Performance Standards for New and Modified Gas Turbine Facilities; and
3. Performance Standards for New and Modified Stationary Internal Combustion Engines.

These are currently scheduled to be published as proposed standards by mid-1978.

APPENDIX C

SUMMARY OF PAST CCEA ACTIVITIES

APPENDIX C

SUMMARY OF PAST CCEA ACTIVITIES

In order to establish some idea of the scope of research activity dealing with the assessment of the effects of pollutants from conventional combustion sources, a literature search was performed through the North Carolina Science and Technology Research Center, using the computer data bases of the following files: ERDA, ENGINEERING INDEX, SSIE, ENERGY LINE and POLLUTION. The search was keyed on air pollution associated with fuel combustion, seeking articles and reports published in the period 1970-1976. Some 477 citations were identified as pertinent.

From these citations, several items of interest were distilled. The first was a list of domestic organizations involved in such research, shown in Table C.1. This list is by no means exhaustive. The next item of interest was the subjects addressed in the research. These were categorized by assessment element, as shown in Table C.2. It should be pointed out that the sum of the right hand column of Table C.2 greatly exceeds 477 because many of the articles and reports dealt with several assessment element topics.

A third item of interest was a comparison of activity in the sectors addressed over the period of the survey. This was obtained by a census of articles by sector/media: utilities/air, industrial/air, residential/air. The commercial-institutional sector did not appear to be covered. Another category in which there was a very large amount of activity was in the relationship of pollutants emitted or control methods suitable for the emissions associated with various fuel types. The results of this crude census are shown in Figure C.1. From this figure it can be seen that fuel-related CPA research has been consistently strong. Research reporting on air emissions and controls for utilities peaked in '73 and '74 and has since subsided to some extent. Research on air emissions and controls for industrial sources has overtaken and passed that for utilities. Compared to the other categories research on residential source emissions and controls has been low key.

Consideration of the data in Table C.2 shows that discussion of pollution controls received the largest attention, with the identification of pollutants and determination of pollutant loadings coming next. Fuel and source characterization were next in order of attention.

Several caveats must be stated with regard to this data. The first is that the computer data bases used have not existed for many years. Consequently, the tendency has been to store only current literature citations. Hence, the small number of citations for 70--72 are probably an artifact. A second caveat is that the archival storage in such data bases is not exhaustive. Coverage grows as support and need grows. A third caveat is that searches of computer data bases depend heavily on selection and combination of the proper keywords for access. Keywords assigned by various authors or programmers do not always agree completely. A fourth caveat is that this particular search was keyed primarily on air pollution. It did not explicitly mention water, effluents, solid wastes, health effects, or ecological effects.

With these caveats in mind, the most defensible conclusion that can be drawn from this preliminary survey is that from 1970 through 1976 a large number of domestic organizations have been involved in research on what kinds of pollutants are emitted, how they can be controlled and what their impacts might be. Further, it seems that the tempo of the research has increased as public and institutional awareness has increased and as Federal and State pollution regulations have been promulgated.

A better defined data base for CCEA activity is provided by the record of projects sponsored by EPA's Industrial Environmental Research Laboratory. Up until mid-1975, IERL program activities were primarily directed to process characterization and pollution control development directed primarily to air pollution from stationary sources. Following the re-organization of EPA's Office of Research and Development (ORD) on June 30, 1975, IERL's pollution control activities began to span a wider range, a multimedia approach concerned with pollution in air, water, solid waste, thermal discharge and energy conservation vís-a-vís pollution control. In addition, cooperative efforts with other EPA laboratories and other Federal agencies have been undertaken to build programs which consider and include all aspects of environmental assessment in order to make explicit the alternative approaches to balancing the demands of minimum environmental quality degradation, economic constraints, and energy constraints. This maturation into a broader outlook can be seen in tracing the topics dealt with by IERL project reports.

In the following pages in this Appendix is a series of Tables giving IERL project report titles. The tables are organized into the following categories:

Table C.3	Reports on Emissions Characterization, Measurement Methodology and Measurements.
Table C.4	Reports on SO_2 Control Processes
Table C.5	Reports on NO_x Control Processes
Table C.6	Reports on Particulate Matter Control Processes
Table C.7	Reports on Economic, Energy and Resource Recovery or Conservation Factors

Table C.8 Reports on Multi-Media Impacts and Goals

Within each category the project reports are arranged by date of publication to show the sequence of research coverage.

From Table C.3 it can be seen that a variety of sources were investigated in order to characterize steady-state and transient operation emissions: utility boilers, industrial boilers, municipal incinerators, residential heaters. The effects of a variety of fuels were examined: coals, oils and solid wastes. Measurement methodology progressed from that for the criteria gases and particulate matter to that for organics and trace materials. Particular attention was given to development of methods for measurement of fine particles, determination of particle size distributions, measuring fugitive emissions, and measuring sulfate, nitrates and acid aerosols.

The intensive effort to develop economic and effective methods for flue gas SO_2 removal can be traced in Table C.4. The projects ranged from studies of the basic chemistry and mass transport factors involved in SO_2 control processes, through pilot plant studies, through studies on large scale plants, to studies of how to deal with the by-products from the SO_2 control processes. Economic studies of SO_2 control processes are shown in Table C.7, along with studies of the economic feasibility of recycling scrubbing reagents and resource recovery.

A similar evolution can be seen in the research efforts to develop NO_x control methods, traced in the report titles given in Table C.5. Early studies investigated post-combustion removal methods by sorbents, catalytic converters or scrubbers. Fundamental research on flame chemistry, however, indicated that NO_x control might be effected in the combustion process itself.

This approach began to be evaluated in field studies as well as in the laboratory.

Research on effective particle collection processes for conventional stationary combustion sources has been carried out along several routes: electrostatic precipitators (ESPs), fabric filtration, wet scrubbing, agglomeration techniques to convert fine particles to the more easily captured larger sizes, and high gradient magnetic separation.

As the engineering problems in developing effective control methods and pollutant measurement methods to quantitate control process effectiveness have become more manageable, the transition to a broader outlook can be traced through the topics addressed in IERL research reports which have been given in the tables in this Appendix and was shown to be even more apparent in Sections VI and VII which discussed more recent and current IERL research programs.

TABLE C.1 DOMESTIC ORGANIZATIONS PERFORMING CCEA RESEARCH

IGT
Battelle, Columbus
KVB
Penn. State Univ.
Wash. State Univ.
Univ. Arizona
Exxon Res. & Engr. Gov't Res. Lab
CEA, Inc.
Radian Corp.
U. Missouri
Iowa Pub. Ser. Co.
W. F. Libby Labs
TRW
UCLA, School Engr.
Federal Power Commission
Sandia Labs
Shell Dev. Co.
Ames Lab., Iowa
Consolidated Edison Co.
Acurex Corp.
Argonne National Labs
MIT
Westinghouse Res. Lab
Conn. Dept. Env. Protection
Marshall and Williams Co.
Pope, Evans & Robbins, Inc.
Applied Technology Corp.
New England Power Service Co.
Walden Res. Corp.
Bechtel
Rockwell International
Penn. Power and Light
Inland Steel
ERDA, Pittsburgh
Bu. Mines, Metal Res. Center
Gulf Res. & Develop. Corp.
Pratt & Whitney Aircraft
Purdue Univ.
Envirotech
U.S. Utility Service Corp.
A. D. Little, Inc.
General Motors, Warren Mich.
ORNL
I. U. Conversion Syst., Inc.
U. Pittsburgh
So. Cal. Edison
Peabody Engr. Sys.
Skelly and Loy, Harrisburg, Pa.
National Lime Assoc.
Chas. T. Main, Inc.
Fluor Engr. & Construction Co.
Betz Lab, Inc.
Apollo Chem. Corp.
Clemson Univ.
VPI
Enviro-Syst. and Res., Inc.
Foster-Wheeler Energy Corp.
Combustion Engineering, Inc.
Smith Tool, Irvine, Calif.
U. Colorado
ASARCO, N.J.
Babcock & Wilcox
Alcoa
Inland Steel
Abcor, Inc.
Nat. Steel Corp., W.Va.
W.Va. Univ. Coal Res. Bur.
W.Va. Univ.
Minn. Power & Light
Am. Gas Assoc.
Midland-Ross Co.
U. Illinois
Rensselaer PolyTechn.
Nat. Coun. Pulp & Paper Ind.
Salem Corp., Pittsburgh, Pa.
Reynolds Met. Co.
Weyerhauser
Long Island Light Co.
Commonwealth Edison Co., Chicago
Union Camp Corp., Savannah
Univ. Oil Prod.
IBM, New Orleans
Stone & Webster Engr. Co.
Maxon Corp.
Riley Stoker Corp.
Inspiration Copper Co.
SUNY
Bitum. Coal Res., Pa.
Stevens Inst. Techn.
Chemetron Corp.
Union Carbide
Nat. Coal Assoc.
Amer. Iron & Steel Inst.

TABLE C-2 DISTRIBUTION OF ARTICLES AND REPORTS BY ASSESSMENT ELEMENT CATEGORY

	Assessment Element	Number of Articles and Reports
1.	Source Characterization	70
2.	Determination of Material Inputs	60
3.	Identification of Pollutants	93
4.	Identification of Media for Each Pollutant	11
5.	Determination of Pollutant Loadings	83
6.	Fugitive Emission Analysis	4
7.	Operating Parameter Sensitivity Analysis	71
8.	Controls	342
9.	Combined Effects Assessment	3
10.	Cross-Media Effects Assessment	1
11.	Environmental Conversion Assessment (Secondary Pollutants)	5
12.	Health Effects	1
13.	Ecological Effects	15
14.	Energy Analysis	28
15.	Economic Analysis	28

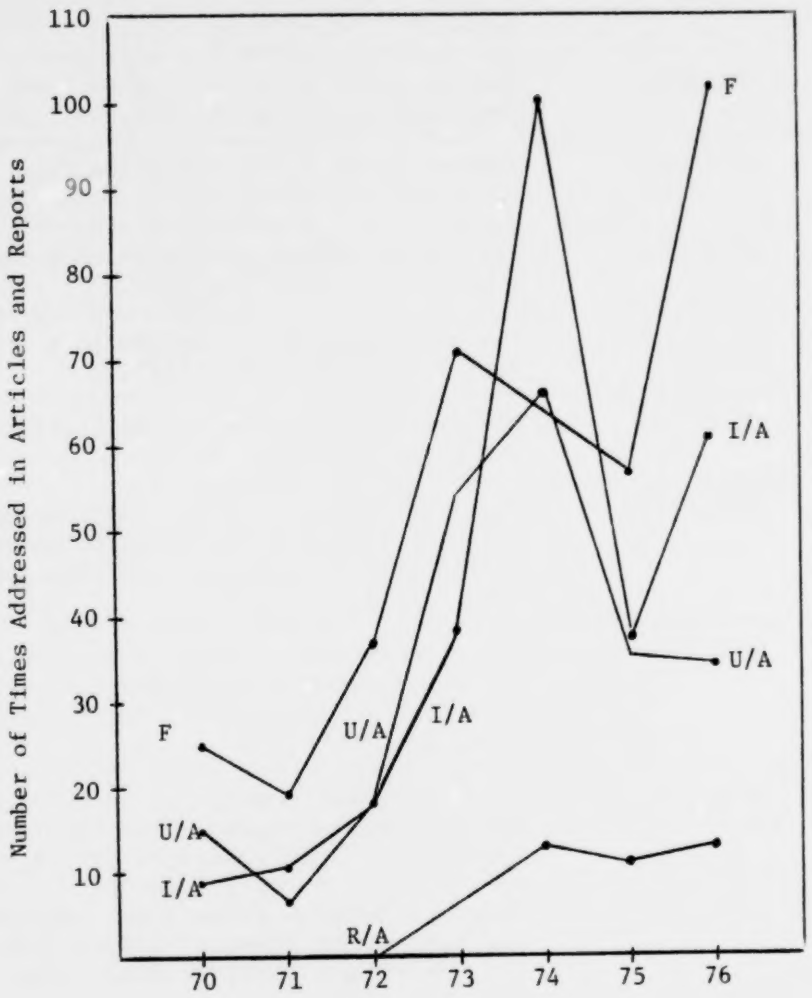

Figure C-1. Results of citation census for CCEA research in categories of utility/air (U/A), industry/air (I/A), residential/air (R/A), and pollutants and controls related to various fuel types (F).

TABLE C.3 REPORTS ON EMISSIONS CHARACTERIZATION, MEASUREMENT METHODOLOGY AND MEASUREMENTS ON CONVENTIONAL COMBUSTION SOURCES

Contractor	EPA Report No.	Report Title and Date
A. D. Little	APTD 1283	Systems Study of Air Pollution from Municipal Incineration, Vol. I - 3/70
A. D. Little	APTD 1284	Systems Study of Air Pollution from Municipal Incineration, Vol. II - 3/70
A. D. Little	APTD 1285	Systems Study of Air Pollution from Municipal Incineration, Vol. III - 3/70
Aerojet General	APTD 1111	Systems Evaluation of Refuse as a Low Sulfur Fuel, Vol. I - 11/71
Aerojet General	APTD 1112	Systems Evaluation of Refuse as a Low Sulfur Fuel, Vol. II - 11/71
IERL-RTP	AP-87	Effects of Fuel Additives on Distillate Oil-Fired Furnaces - 6/71
Thermo-Systems	APTD 0733	State of the Art: 1971: Instrumentation for Measurement of Particulate Emissions from Combustion Sources: Particulate Mass - 1971
Thermo-Systems	APTD 0734	State of the Art: 1971: Instrumentation for Measurement of Particulate Emissions from Combustion Sources: Particulate Mass, Vol. II - 1971
Walden Research	APTD 1106	Improved Chemical Methods for Sampling and Analysis of Gaseous Pollutants from the Combustion of Fossil Fuels: SO_x - 6/71
Walden Research	APTD 1108	Improved Chemical Methods for Sampling and Analysis of Gaseous Pollutants from the Combustion of Fossil Fuels: SO_x, Vol. II - 7/71
Walden Research	APTD 1109	Improved Chemical Methods for Sampling and Analysis of Gaseous Pollutants from the Combustion of Fossil Fuels: SO_x, Vol. III - 7/71

TABLE C.3 (Continued)

Contractor	EPA Report No.	Report Title and Date
Walden Research	APTD 0924	Systematic Study of Air Pollution from Intermediate-Size Fossil Fuel Combustion Equipment - 7/71
Thermo-Systems	APTD 1524	State of the Art 1971: Instrumentation for the Measurement of Particulate Emissions from Combustion Sources: Vol. III, Particulate Size - 7/72
TRW	R2-73-172	Instrumental Analysis for Wet Scrubbing Processes - 1/72
Processes Research	R2-73-241	Air Pollution from Fuel Combustion in Stationary Sources - 10/72
W. C. McCrone	650/2-73-024	Measurement and Characterization of Particles in the Wet Scrubbing Process for SO_x Control - 7/72
Battelle	R2-73-084a	Field Investigation of Emissions from Combustion Equipment for Space Heating - 6/73
Battelle	R2-73-084b	Field Investigation of Emissions from Combustion Equipment for Space Heating: Data Supplement - 6/73
Battelle	R2-73-216	Chemical Composition of Particulate Air Pollutants from Fossil Fuel Combustion Sources - 3/73
Southern Research Institute	650/2-73-035	Field Measurements of Particle Size Distribution with Inertial Sizing Devices 10/73
Thermo-Systems	650/2-73-022	State of the Art 1971: Instrumentation for the Measurement of Particulate Emissions from Combustion Sources: Vol. IV Final Report - 9/73
Thermo-Systems	650/2-73-031	Effectiveness of Selective Fuel Additives in Controlling Pollution Emissions from Residual-Oil-Fired Boilers - 10/73

TABLE C.3 (Continued)

Contractor	EPA Report No.	Report Title and Date
UltraSystems, Inc.	R2-73-292a	Experimental Combustor for the Development of Package Boiler Emission Control Techniques: Phase I - 7/73
Walden Research	R2-73-191	Systems Study of Conventional Combustion Sources in the Primary Aluminum Industry 4/73
Walden Research	R2-73-192	Systems Study of Conventional Combustion Sources in the Iron and Steel Industry - 4/73
Aerotherm	650/2-74-067	Design, Development and Fabrication of a Prototype, High-Volume Particulate Mass Sampling Train - 5/74
Battelle	650/2-74-026	Investigation of Particulate Emissions from Oil-Fired Residential Heating Units 3/74
IERL-RTP	650/2-74-003	A Study of Air Pollutant Emissions from Residential Heating Systems - 1/74
Midwest Research	650/2-74-073	St. Louis/Union Electric Refuse Firing Demonstration Air Pollution Test Report 8/74
Monsanto	650/2-74-117	Sources and Characterization of Fine Particulate Test Dusts - 11/74
Monsanto	[not in APTIC]	Briefing Document on SO_2 Emissions Data Base - 6/74
Radian	650/2-74-024	Development of Sampling and Analytical Methods of Lime/Limestone West Scrubbing Tests - 3/74
Rockwell International	650/2-74-047	Design of an Optimum Distillate Oil Burner for Control of Pollutant Emissions 6/74

TABLE C.3 (Continued)

Contractor	EPA Report No.	Report Title and Date
Southern Research Institute	650/2-74-102	Particulate Sizing Techniques for Control Device Evaluation - 10/74
TRW	650/2-74-031a	Application of Holographic Methods to the Measurement of Flames and Particulate - 4/74
TRW	650/2-74-031b	Application of Holographic Methods to the Measurement of Flames and Particulate, Vol. II - 4/74
TRW	650/2-74-064	Instrumental Analysis for Wet Scrubbing Processes - 7/74
Midwest Research	650/2-75-066	Hazardous Emission Characterization of Utility Boilers - 7/75
RTI	600/2-75-022	Effects of Transient Operating Conditions on Steam-Electric Generator Emissions - 8/75
Southern Research Institute	650/2-74-102a	Particulate Sizing Techniques for Control Device Evaluation - 8/75
TRW	600/2-75-012	Continuous Measurement of Gas Composition from Stationary Sources - 7/75
Aerospace	600/7-76-012	Inventory of Combustion Related Emissions from Stationary Sources - 9/76
Battelle	650/2-76-029	Emissions from Residential and Small Commercial Stoker-Coal-Fired Boilers Under Smokeless Operation - 10/76
Battelle	600/2-76-056	Comparison of Fossil and Wood Fuels - 3/76
Battelle	600/2-76-102	Environmental Aspects of Retrofitting Two Industries to Low and Intermediate Energy Gas from Coal - 4/76

TABLE C.3 (Continued)

Contractor	EPA Report No.	Report Title and Date
Battelle	600/2-76-268	Blast Furnace Slips and Accompanying Emissions as an Air Pollution Source - 10/76
ERDA	600/2-76-075	Analysis of Polycyclic Organic Matter in Coal, Coal Ash, Fly Ash and Other Fuel and Emission Samples - 3/76
GCA	600/2-76-046a	Preliminary Emissions Assessment of Conventional Stationary Combustion Systems, Vol. I, Exec. Summary - 3/76
GCA	600/2-76-046b	Preliminary Emissions Assessment of Conventional Stationary Combustion Systems, Vol. II - 3/76
GCA	600/2-76-046c	Preliminary Emissions Assessment of Conventional Stationary Combustion Systems, Vol. III - 8/76
IERL-RTP	600/7-76-027	Effect of Fly Ash Conditioning Agent on Power Plant Emissions - 10/76
Institute of Gas Technology	600/7-76-022	Survey of Emissions Control and Combustion Equipment Data in Industrial Process Heating - 10/76
KVB Engrg.	600/2-76-086b	Field Testing: Trace Element and Organic Emissions from Industrial Boilers - 10/76
Midwest Research	600/2-76-209	Performance of Emission Control Devices on Boilers Firing Municipal Solid Waste and Oil - 7/76
Mitre	600/2-76-137	Evaluation of Selected Methods for Chemical and Biological Testing of Industrial Particulate Emissions - 5/76
Monsanto	600/7-76-028	PCB Emissions from Stationary Sources - 10/76
Monsanto	600/2-76-201	Utility of Solid Sorbents for Sampling Organic Emissions from Stationary Sources 7/76

TABLE C.3 (Continued)

Contractor	EPA Report No.	Report Title and Date
Radian	600/2-76-092	Total Suspended Particulates: Review and Analysis - 4/76
outhern Research Institute	600/2-76-280	Particulate Sizing Techniques for Control Device Evaluation: Cascade Impactor Calibration - 10/76
TRC	600/2-76-089a	Technical Manual for Measurement of Fugitive Emissions: Upwind/Downwind Sampling Method for Industrial Emissions - 5/76
TRC	600/2-76-089b	Technical Manual for Measurement of Fugitive Emissions: Roof Monitor Sampling Method for Industrial Fugitive Emissions - 5/76
TRC	600/2-76-089c	Technical Manual for Measurement of Fugitive Emissions: Quasi-Stack Sampling Method for Industrial Fugitive Emissions - 5/76
TRC	600/2-76-246	Symposium on Fugitive Emissions Measurement and Control - 9/76
TRC	600/2-76-284	Development of Procedures for the Measurement of Fugitive Emissions - 12/76
TRW	600/2-76-283	Measurement Techniques for Inorganic Trace Materials in Control Stream Systems - 12/76
Aerospace	600/2-77-066a	Inventory of Combustion Related Emissions from Stationary Sources (First Update) - 3/77
Battelle	600/2-77-008a	Combustion Additives for Pollution Control -- A State-of-the-Art Review - 1/77
Battelle	600/2-77-008b	Experimental Evaluation of Fuel Oil Additives for Reducing Emissions and Increasing Efficiency of Boilers - 1/77

TABLE C.3 (Continued)

Contractor	EPA Report No.	Report Title and Date
Battelle	600/7-77-041	A Survey of Sulfate, Nitrate, and Acid Aerosol Emissions and Their Control - 4/77
Catalytic, Inc.	600/7-77-081	Process Technology Background for Environmental Assessment/Systems Analysis Utilizing Fuel Oil - 8/77
GCA	600/2-77-077	Design, Development and Fabrication of a Fine Particulate Measuring Device - 4/77
IERL-RTP	600/2-77-115	Environmental Assessment Sampling and Analysis: Phased Approach and Techniques for Level I - 6/77
TVA	600/7-77-010	Characterization of Ash from Coal Fired Power Plants - 1/77

TABLE C.4 REPORTS ON SO_2 CONTROL PROCESSES FOR CONVENTIONAL COMBUSTION SOURCES

Contractor	EPA Report No.	Report Title and Date
Aerojet General	APTD 0619	Applicability of Aqueous Solutions to the Removal of SO_2 from Flue Gases, Vol. I - 10/70
Aerojet General	APTD 0620	The Development of New and/or Improved Aqueous Processes for Removing SO_2 from Flue Gas, Vol. II - 10/70
Allied Chemical	APTD 0659	Applicability of Reduction to Sulfur Techniques to the Development of New Processes for Removing SO_2 from Flue Gases - 11/70
Allied Chemical	APTD 0660	Applicability of Reduction to Sulfur Techniques to the Development of New Processes for Removing SO_2 from Flue Gases, Vol. II 11/70
Ambient Purification Technology	[None]	Wet Scrubber Systems Study - 1/70
Atomic International	APTD 1238	Development of a Molten Carbonate Process for Removal of SO_2 from Power Plant Stack Gases - 1/70
Atomic International	APTD 1239	Development of a Molten Carbonate Process for Removal of SO_2 from Power Plant Stack Gases, Part II - 1/70
Atomic International	APTD 1240	Development of a Molten Carbonate Process for Removal of SO_2 from Power Plant Stack Gases, Part III - 1/70
Atomic International	APTD 1241	Development of a Molten Carbonate Process for Removal of SO_2 from Power Plant Stack Gases, Part IV - 1/70
Atomic International	APTD 1242	Development of a Molten Carbonate Process for Removal of SO_2 from Power Plant Stack Gases, Part V - 1/70
Atomic International	APTD 1243	Development of a Molten Carbonate Process for Removal of SO_2 from Power Plant Stack Gases, Part VI - 1/70

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
Atomic International	APTD 1244	Development of a Molten Carbonate Process for Removal of SO_2 from Power Plant Stack Gases, Part VII - 1/70
Babcock & Wilcox	APTD 1176	Additive Injection for SO_2 Control -- Pilot Plant Study - 3/70
Babcock & Wilcox	APTD 0648	Magnesia Base Wet Scrubbing of Pulverized Coal Generated Flue Gas - Pilot Demonstration - 9/70
Babcock & Wilcox	APTD 0649	Magnesia Base Wet Scrubbing of Pulverized Coal Generated Flue Gas, Addendum - 12/70
General Electric	APTD 1259	Immobilized Liquid Membranes for SO_2 Separation - 3/70
M. W. Kellogg	APTD 0688	Removal of SO_2 from Power Plant Flue Gases Using the Alkalized Alumina Process - 2/70
Mitre	APTD 0843	An Examination of Alkali Injection -- Wet Scrubber Demonstration Project - 11/70
Monsanto	APTD 0675	Applicability of Catalytic Oxidation to the Development of New Processes for Removing SO_2 from Flue Gases - 7/69
Monsanto	APTD 0675	Applicability of Catalytic Oxidation to the Development of New Processes for Removing SO_2 from Flue Gases, Literature Review - 8/70
Monsanto	APTD 0677	Applicability of Catalytic Oxidation to the Development of New Processes for Removing SO_2 from Flue Gases, Bibliography 8/70
National Acad. of Eng. & Nat. Res. Council	APTD 0571	Abatement of SO_x Emissions from Stationary Combustion Sources - 1970
Radian Corp.	APTD 1287	A Theoretical Description of the Limestone Injection -- Wet Scrubbing Process, Vol. I 6/70

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
Radian Corp.	APTD 1288	A Theoretical Description of the Limestone Injection -- Wet Scrubbing Process, Vol. II - 6/70
Stone & Webster	APTD 1271	SO_2 Scrubbers: Stone & Webster Ionics Process - 1/70
UniRoyal	APTD 0584	Development of Regenerable Fibres for Removal of SO_2 from Waste Gases, Final Report - 7/70
Battelle	APTD 0802	Final Report on the Investigation of the Reactivity of Limestone and Dolomite for Capturing SO_2 from Flue Gases - 10/71
Chemical Constru [sic]	APTD 0768	High Sulfur Combustor Study: Vol. I: Narrative Summary - 2/71
Chemical Constru [sic]	APTD 0769	High Sulfur Combustor Study: Vol. II: Descriptive Detail - 2/71
Consolidation Coal	APTD 1157	Development of the CO_2 Acceptor Process Toward Low-Sulfur Boiler Fuel - 11/71
Cottrel Environmental Systems, Inc.	APTD 1070	Pilot Scale Investigation of a Venturi Type Contactor for Removal of SO_2 by the Limestone Wet Scrubbing Proc. - 10/71
IERL-RTP	APTD 0737	Selected Studies on Alkaline Additives for SO_x Control - 12/71
Illinois State Geological Survey	APTD 0920	Petrographic and Mineralogical Characteristics of Carbonate Rocks Related to SO_2 Sorption in Flue Gases - 7/71
M. W. Kellogg	APTD 0807	Evaluation of SO_2 Control Processes - 10/71
Monsanto	APTD 0676	Applicability of Catalytic Oxidation to the Development of New Processes for Removing SO_2 from Flue Gases - 1/71

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
MSA Research	APTD 0723	Inorganic Liquids for Removing SO_2 from Flue Gases: Phase II - 7/71
North American Rockwell	APTD 0752	Development of a Molten Carbonate Process for Removal of SO_2 from Power Plant Stack Gases - 1/71
Processes Research	[Not in NTIS]	Neutralization of Abatement Derived Sulfuric Acid - 10/71
Radian Corp.	APTD 1183	A Study of the Limestone Injection Wet Scrubbing Process, Vol. I - 11/71
Radian Corp.	APTD 1184	A Study of the Limestone Injection Wet Scrubbing Process, Vol. II - 11/71
Radian Corp.	APTD 1185	A Study of the Limestone Injection Wet Scrubbing Process, Vol. III - 11/71
Stanford Research Institute	APTD 0622	Feasibility of New SO_x Control for Application to Smelters and Power Plants: Part I: Monsanto Cat-Ox Process: Smelter Gases - 2/71
Stanford Research Institute	APTD 0623	Feasibility of New SO_x Control for Application to Smelters and Power Plants: Part II: Wellman-Lord SO_2 Recovery Process, Smelter Gases - 2/71
Stanford Research Institute	APTD 0624	Feasibility of New SO_x Control for Application to Smelters and Power Plants: Part III: Monsanto Cat-Ox Process, Power Plant Flue Gases - 2/71
Stanford Research Institute	APTD 0625	Feasibility of New SO_x Control for Application to Smelters and Power Plants: Part IV: Wellman-Lord Recovery Process: Power Plant Flue Gases
TVA	APTD 0699	Investigation of the Reactivities of Limestone to Remove SO_2 from Flue Gas - 1971

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
U.S. Bureau of Mines	APTIC 34429	Evaluation of Some Solid Oxides as Sorbents of SO_2 - 1971
Ambient Purification Technology	R2-72-118a	Wet Scrubber Systems Study, Vol. I - 8/72
Ambient Purification Technology	R2-72-118b	Wet Scrubber Systems Study, Vol. II - 8/72
Applied Technology	R2-72-035	SO_2 Free Two Stage Coal Combustion Process 8/72
Applied Technology	R2-72-035a	SO_2 Free Two Stage Coal Combustion Process Appendices - 8/72
IERL-RTP	APTD 1161	Procedings of Second International Lime/Limestone Wet Scrubbing Symposium 11/8-12/71 - 6/72
M. W. Kellogg	R2-72-100	Applicability of SO_2 Control Processes to Power Plants - 11/72
M. W. Kellogg	APTD 1136	Review of the Dry Limestone Injection Process - 5/72
Processes Research	APTD 1066	Recent Developments in Desulfurization of Fuel Oil and Waste Gas in Japan - 1/72
Stanford University	[Not in System]	Sulfation Kinetics in SO_2 Absorption from Stack Gases - 6/72
West Virginia University	R2-72-027	Pilot Scale-Up of Processes to Demonstrate Utilization of Pulverized Coal Fly Ash Modified by Addition of Limestone Dolomite SO_2 Removal Additive - 3/72
Bechtel	650/2-73-013	EPA Alkali Scrubbing Test Facility: Sodium Carbonate and Limestone Test Results - 8/73

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
IERL-RTP	R2-73-186	Regeneration Chemistry of Sodium-Based Double Alkali Scrubbing Process - 3/73
IERL-RTP	650/2-73-012	Properties of Ammonium Sulfate, Ammonium Bisulfate, and SO_2 Solutions in Ammonia Scrubbing Process - 8/73
IERL-RTP	650/2-73-029	Interactions of Stack Gas Sulfur and Nitrogen Oxides on Dry Sorbents - 9/73
IERL-RTP	650/2-73-038	Procedings of the Flue Gas Desulfurization Symposium, 1973 - 12/73
Illinois State Geological Survey	650/2-73-044	Petrographic Characteristics and Physical Properties of Marls, Chalks, Shells and Their Calcines Related to Desulfurization of Flue Gases - 7/71
M.I.T.	650/2-73-047	Absorption of SO_2 into Limestone Slurrys: Absorption Rates and Kinetics - 12/73
Processes Research	R2-73-187	Recent Developments in Desulfurization of Fuel Oil and Waste Gas in Japan - 4/73
Processes Research	R2-73-229	Recent Developments in Desulfurization of Fuel Oil and Waste Gas in Japan - 5/73
TVA	650/2-73-019a	Full Scale Desulfurization of Stack Gas by Dry Limestone Injection, Vol. I - 8/73
TVA	650/2-73-019b	Full Scale Desulfurization of Stack Gas by Dry Limestone Injection, Vol. II - 8/73
TVA	650/2-73-019c	Full Scale Desulfurization of Stack Gas by Dry Limestone Injection, Vol. III- 8/73
West Virginia University	650/2-73-003	Absorption of SO_2 by Alkaline Solutions in Venturi Scrubber Systems - 7/73
Aerospace	650/2-74-037a	Disposal of By-Products from Non-Regenerable FGD Systems (Initial Report) - 5/74
A.P.T. Inc.	650/2-74-119a	Entrainment Separators for Scrubbers - 10/74

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
Bechtel	650/2-74-010	EPA Alkali Scrubbing Test Facility: Limestone Wet Scrubbing Test Results - 1/74
Engineering Science	650/2-74-077	Lime/Limestone Scrubbing in a Pilot Dustraxtor (sic) - Key West - 9/74
Engineering Science	[Not in System]	Lime/Limestone Scrubbing in a Pilot Dustraxtor (sic) - Key West - Addendum Data - 9/74
IERL-RTP	650/2-74-050	Measurement of Entrained Liquid Levels in Effluent Gases from Scrubber Demisters - 6/74
IERL-RTP	650/2-74-035	Evaluation of Equations for Designing Ammoniacal Scrubbers to Remove Sulfur Oxides from Waste Gas - 1/74
IERL-RTP	650/2-74-126a	Procedings: Symposium on Flue Gas Desulfurization: Atlanta 11/74: Vol. I - 12/74
IERL-RTP	650/2-74-126b	Procedings: Symposium on Flue Gas Desulfurization: Atlanta 11/74: Vol. II - 12/74
M. W. Kellogg	650/2-74-127	Evaluation of SO_2 Emission Control Options for Iowa Power Boilers - 12/74
Radian	650/2-75-006	A Theoretical and Experimental Study of the Lime/Limestone Wet Scrubbing Process - 12/74
Southern Research Institute	650/2-74-129	Evaluation of Aronetics Two-Phase Jet Scrubber - 12/74
Stanford Research Institute	650/2-74-108	Wet-Scrubber Liquid Utilization
TVA	650/2-74-049a	Pilot Plant Study of an Ammonia Absorption - Ammonium Bisulfate Regeneration Process 6/74

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
A.P.T. Inc.	650/2-74-119b	Entrainment Separators for Scrubbers - Final Report - 8/75
Bechtel	650/2-75-047	EPA Alkali Scrubbing Test Facility: Summary of Testing through 10/74 - 6/75
Bechtel	600/2-75-050	EPA Alkali Scrubbing Test Facility: Advanced Program - 9/75
Chemical Constru (sic)	600/2-75-057	Magnesia Scrubbing Process as Applied to an Oil-Fired Power Plant - 10/75
Combustion Engineering	650/2-75-052	Lime/Limestone Scrubbing for SO_2 and Particulate Removal in a Marble Bed Scrubber 6/75
GCA	650/2-74-083a	Dynactor Scrubber Evaluation - 6/75
GCA	650/2-75-054	Overview of EPA-IERL/RTP Scrubber Programs 9/75
IERL-RTP	650/2-75-010a	Sulfur Oxide Throwaway Sludge Evaluation Panel (Sotsep), Vol. I - 4/75
IERL-RTP	650/2-75-010b	Sulfur Oxide Throwaway Sludge Evaluation Panel (Sotsep), Vol. II - 4/75
M. W. Kellogg	650/2-75-098a	Evaluation of R&D Investment Alternatives for SO_x Air Pollution Control Processes - 8/75
Monsanto	600/2-75-045	Method for Evaluating SO_2 Abatement Strategies - 9/75
PEDCo	650/2-75-057a	Survey of FGD Systems: Arizona Public Service Co., Cholla Generating Station - 6/75
PEDCo	650/2-75-057b	Survey of FGD Systems: LaCygne Power Station, Kansas City Power & Light Co. - 7/75

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
PEDCo	650/2-75-057c	Survey of FGD Systems: Phillips Power Station, Duquesne Light Co. - 7/75
PEDCo	650/2-75-057d	Survey of FGD Systems: Paddy's Run Station, Louisville Gas & Electric - 8/75
PEDCo	650/2-75-057e	Survey of FGD Systems: Lawrence Power Station, Kansas Power & Light - 9/75
PEDCo	650/2-75-057f	Survey of FGD Systems: Eddystone Station, Philadelphia Electric Co. - 9/75
PEDCo	650/2-75-057g	Survey of FGD Systems: Dickerson Station, Potomac Electric Power Co. - 9/75
PEDCo	650/2-75-057h	Survey of FGD Systems: Hawthorne Station, Kansas City Power & Light Co. - 9/75
PEDCo	650/2-75-057i	Survey of FGD Systems: Will County Station, Commonwealth Edison Co. - 10/75
PEDCo	650/2-75-057k	Survey of FGD Systems: Mojave Station, Southern Cal. Edison Co. - 10/75
PEDCo	650/2-75-057j	Survey of FGD Systems: Reid Gardner Station, Nevada Power Co. - 10/75
Southern Research Institute	650/2-74-129a	Evaluation of Centrifield Scrubber - 6/75
West Virginia University	600/2-75-023	Absorption of SO_2 in Spray Column and Turbulent Contacting Absorbers - 8/75
Aerospace	600/2-76-070	Disposal of Flue Gas Cleaning Wastes: EPA Shawnee Field Evaluation: Initial Report 3/76
Aerospace	600/7-76-018	Control of Waste and Water Pollution from Power Plant Flue Gas Cleaning Systems: First Annual R&D Report - 10/76
Battelle	600/2-75-038	Reductant Gases for Flue Gas Desulfurization Systems - 5/76

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
Bechtel	600/7-76-008	EPA Alkali Scrubbing Test Facility: Advanced Program - 9/76
IERL-RTP	600/2-76-136a	Procedings: Symposium on FGD: New Orleans - 3/76, Vol. I - 5/76
IERL-RTP	600/2-76-136b	Procedings: Symposium on FGD: New Orleans - 3/76, Vol. II- 5/76
IERL-RTP	600/2-76-279	Equilibrium Partial Pressure of SO_2 in Alkaline Scrubbing Processes - 1976
PEDCo	600/2-76-013a	SO_2 Abatement for Stationary Sources in Japan - 1/76
Radian	600/2-76-281	Desulfurization of Steel Mill Sinter Plant Gases - 10/76
Radian	600/2-76-273a	Experimental & Theoretical Studies of Solid Solution Formation in Lime and Limestone SO_2 Scrubbers, Vol. I - 10/-6
Radian	600/2-76-273b	Experimental & Theoretical Studies of Solid Solution Formation in Lime and Limestone SO_2 Scrubbers, Vol. II - 10/76
RTI	600/2-76-008	SO_2 Control Processes for Non-Ferrous Smelters - 1/76
RTI	600/2-76-080	A Quality Assurance Program for the EPA/Shawnee Wet Limestone Scrubber Demonstration Program - 3/76
Aerospace	600/7-77-052	Disposal of By-Products from Non-Regenerable FGD Systems, Second Progress Report - 5/77
A. D. Little	600/7-77-005	Evaluation of the General Motors Double Alkali SO_2 Control System - 1/77
A. D. Little	600/7-77-050a	Final Report: Dual Alkali Test and Evaluation Program, Vol. I - 5/77

TABLE C.4 (Continued)

Contractor	EPA Report No.	Report Title and Date
A. D. Little	600/7-77-051	An Evaluation of the Disposal of FGD Wastes in Mines and the Ocean, Initial Assessment - 5/77
A.P.T. Inc.	600/2-77-172	Venturi Scrubber Performance Model - 8/77
Chemico	600/2-77-018	Magnesia Scrubbing Applied to an Oil-Fired Power Plant - 3/77
ERDA	600/7-77-075	FGD Using Fly Ash Derived from Western Coals - 7/77
IERL-RTP	600/7-77-061	Sludge Oxidation in Limestone FGD Scrubbers - 6/77
TRW	600/7-77-014	Demonstration of Wellman-Lord/Applied Chemical FGD Technology: Boiler Operating Characteristics - 2/77
West Virginia University	600/7-77-026	Analysis and Simulation of Recycle SO_2 Lime Slurry in TCA Scrubber System - 3/77

TABLE C.5 REPORTS ON NO_x CONTROL PROCESSES FOR CONVENTIONAL COMBUSTION SOURCES

Contractor	EPA Report No.	Report Title and Date
Babcock & Wilcox	650/2-73-015	Equimolar NO-NO_2 Absorption into Magnesia Slurry -- A Pilot Feasibility Study - 11/71
Esso	APTD 1163	Systematic Field Study of NO_x Emission Control Methods for Utility Boilers - 12/71
Radian	APTD 1162	A Theoretical Study of NO_x Absorption Using Aqueous Alkaline and Dry Sorbents, Vol. I - 12/71
Radian	APTD 1138	A Theoretical Study of NO_x Absorption Using Aqueous Alkaline and Dry Sorbents, Vol. II - 12/71
Catalytic Inc.	R2-72-072a	State of the Art for Controlling NO_x Emissions, Part I, Utility Boilers
Esso	APTD 1168	Laboratory Studies and Mathematical Modelling of NO_x Formation in Combustion Processes - 1972
Esso	R2-72-015	Development of the Aqueous Processes for Removing NO_x from Flue Gases - 9/72
National Acad. of Eng. & Nat. Res. Council	APTD 0982	Abatement of NO_x Emissions from Stationary Sources - 1972
Aerospace	650/2-73-014	Investigation of Surface Combustion Concepts for NO_x Control in Utility Boilers and Stationary Gas Turbines - 8/73
Combustion Engineering	650/2-73-005	Program for Reduction of NO_x from Tangential Coal Fired Boilers, Phase I - 8/73
Esso	R2-72-015a	Development of the Aqueous Processes for Removing NO_x from Flue Gases: Addendum 6/73
Institute of Gas Technology	650/2-73-033a	Aerodynamic Control of NO_x and Other Pollutants from Fossil Fuel Combustion, Vol. I - 10/73

TABLE C.5 (Continued)

Contractor	EPA Report No.	Report Title and Date
Institute of Gas Technology	650/2-73-033b	Aerodynamic Control of NO_x and Other Pollutants from Fossil Fuel Combustion, Vol. II - 10/73
Processes Research	R2-73-284	Nitrogen Oxide Abatement Technology in Japan - 6/73
Aerotherm	650/2-74-091	Systems Analysis Requirements for NO Control of Stationary Sources - 9/74
Babcock & Wilcox	650/2-74-002a	Effects of Design and Operating Variables on NO_x from Coal Fired Furnaces, Phase I - 1/74
Exxon	650/2-74-066	Field Testing: Application of Combustion Modifications to Control NO_x Emissions from Utility Boilers - 6/74
Ultrasystems Inc.	R2-73-292b	Package Boiler Flame Modifications for Reducing Nitrogen Oxide Emissions - 6/74
U.S. Bureau of Mines	650/2-74-038	Combustion Control of Pollutants from Multi-Burner Coal Fired Systems - 5/74
Aerospace	650/2-75-012	Analysis of Test Data for NO_x Control in Gas and Oil-Fired Utility Boilers - 1/75
Aerotherm	600/2-75-046	NO_x Combustion Control Methods and Costs for Stationary Sources - 9/75
Babcock & Wilcox	650/2-74-002b	Effects of Design and Operating Variables on NO_x from Coal Fired Furnaces, Phase II 2/75
Combustion Engineering	650/2-73-005a	Program for Reduction of NO_x from Tangential Coal Fired Boilers, Phase II - 6/75
Combustion Engineering	650/2-73-005b	Program for Reduction of NO_x from Tangential Coal Fired Boilers, Phase III - 8/75
TRW	650/2-75-001a	Assessment of Catalysts for Control of NO_x from Stationary Power Plants, Phase I, Vol. I - 1/75

TABLE C.5 (Continued)

Contractor	EPA Report No.	Report Title and Date
TRW	650/2-75-001b	Assessment of Catalysts for Control of NO_x from Stationary Power Plants, Phase I, Vol. II - 1/75
Aerospace	600/2-76-274	Analysis of Test Data for NO_x Control in Coal Fired Utility Boilers - 10/76
Environics	600/7-76-031	Catalytic Reduction of Nitrogen Oxides with Ammonia: Utility Pilot Plant Operation - 10/76
Exxon	600/7-76-009a	Mechanism and Kinetics of the Formation of NO_x and Other Combustion Pollutants, Phase I, Unmodified Combustion - 8/76
Exxon	600/7-76-009b	Mechanism and Kinetics of the Formation of NO_x and Other Combustion Pollutants, Phase I, Modified Combustion - 8/76
Institute of Gas Technology	600/7-76-098a	Burner Design Criteria for Control of NO_x from Natural Gas Combustion, Vol. I - 4/76
Institute of Gas Technology	600/7-76-098b	Burner Design Criteria for Control of NO_x from Natural Gas Combustion, Vol. II - 6/76
Int. Flame Research Foundation	600/2-76-061a	Burner Criteria for NO_x Control, Vol. I: Influence of Burner Variables on NO_x in Pulverized Coal Flames - 3/76
KVB Engineering	600/2-76-086a	Field Testing: Application of Combustion Modifications to Control Pollutant Emissions from Industrial Boilers, Phase II - 4/76
PEDCo	600/2-76-013b	NO_x Abatement for Stationary Sources in Japan - 1/76
RTI	600/7-76-033	Technology and Economics of Flue Gas NO_x Oxidation by Ozone - 12/76
U.C.L.A.	600/7-76-026	Parametric Studies of Catalysts for NO_x Control from Stationary Power Plants - 10/76

TABLE C.5 (Continued)

Contractor	EPA Report No.	Report Title and Date
Aerotherm	600/7-77-077	EPA Stationary Source Combustion Control Technology Program, FY1976 - 7/77
KVB Engineering	600/8-77-003a	Guidelines for Industrial Boiler Performance Improvement - 1/77
KVB Engineering	600/2-77-122	Field Testing: Application of Combustion Modifications to Control Pollutant Emissions from Industrial Boilers, Phases I & II - 6/77
Monsanto	600/7-77-006	Applicability of NO_x Combustion Modification to Cyclone Boilers - 1/77
Ultrasystems Inc.	600/2-77-025	Reduction of Nitrogen Oxide Emissions from Field Operating Package Boilers - 1/77

TABLE C.6 REPORTS ON PARTICULATE MATTER CONTROLS FOR CONVENTIONAL COMBUSTION SOURCES

Contractor	EPA Report No.	Report Title and Date
Southern Research Institute	APTD 0610	An Electrostatic Precipitator Systems Study: A Manual of Electrostatic Precipitator Technology - 8/70
Southern Research Institute	APTD 0611	An Electrostatic Precipitator Systems Study: A Manual of Electrostatic Precipitator Technology, Part II - 8/70
Southern Research Institute	APTD 0612	An Electrostatic Precipitator Systems Study: A Manual of Electrostatic Precipitator Technology, Part III - 8/70
Southern Research Institute	APTD 0657	An Electrostatic Precipitator Systems Study: A Manual of Electrostatic Precipitator Technology, Final Report - 10/70
Babcock & Wilcox	APTD 0967	Conceptualized Fly Ash System with By-Product Recovery - 1/71
IERL-RTP	[Not in System]	Procedings of the Electrostatic Precipitator Symposium - 2/71
Midwest Research	APTD 0743	Particulate Pollutant System Study, Vol. I 5/71
Midwest Research	APTD 0744	Particulate Pollutant System Study, Vol. II - 8/71
Midwest Research	APTD 0745	Particulate Pollutant System Study, Vol. III - 5/71
MIT	APTD 0869	Electrical Induction of Particle Agglomeration - 8/71
MIT	APTD 0868	Charged Droplet Technology for Removal of Particulates from Industrial Gases - 8/71
National Acad. of Eng. & Nat. Res. Council	R2-72-042	Abatement of Particulate Emissions from Stationary Sources - 7/72

TABLE C.6 (Continued)

Contractor	EPA Report No.	Report Title and Date
Southern Research Institute	650/2-74-132	An Electrostatic Precipitator Performance Model - 7/72
Uni search	R2-73-258	Survey of Austrailian Experience in Collecting High Resistivity Fly Ash with Electrostatic Precipitators
A.P.T. Inc.	650/2-73-036	Feasibility of Flux/Force/Condensation Scrubbing for Fine Particulate Collection 10/73
IERL-RTP	650/2-75-081	Seminar on Electrostatics and Fine Particles - 9/73
A.P.T. Inc.	650/2-74-093	Fine Particle Scrubber Performance Tests 10/74
A.P.T. Inc.	650/2-74-112	EPA Fine Particle Scrubber Symposium, 5/74 10/74
Battelle	650/2-74-100	Process Modifications for Control of Particulate Emissions from Stationary Combustion, Incineration and Metals - 10/74
Cottrell Environmental Systems, Inc.	650/2-74-053	Particulate Collection Study, EPA/TVA Full Scale Dry Limestone Injection Tests - 6/74
Enviro-Systems and Research	650/2-74-058	Applying Fabric Filtration to Coal Fired Industrial Boilers: Preliminary Pilot Scale Investigation - 7/74
GCA	650/2-74-043	Procedings: Symposium on the Use of Fabric Filters for the Control of Submicron Particulates - 5/74
Midwest Research	650/2-74-027	Control Technology for Fine Particulate Emissions - 5/74
MIT	650/2-74-075	Charged Droplet Scrubbing of Submicron Particles - 8/74

TABLE C.6 (Continued)

Contractor	EPA Report No.	Report Title and Date
Southern Research Institute	650/2-74-102	Particulate Sizing Techniques for Control Device Evaluation - 10/74
A.P.T. Inc.	600/2-75-018	Study of Flux Force/Condensation Scrubbing of Fine Particles - 8/75
Enviro-Systems and Research	650/2-74-058a	Applying Fabric Filtration to Coal Fired Industrial Boilers: Pilot Scale Investigation - 8/75
GCA	600/2-75-013a	Fractional Efficiency of a Utility Boiler Baghouse: Nucla Generating Plant - 8/75
M. W. Kellogg	650/2-75-016	Symposium on Electrostatic Precipitators for the Control of Fine Particles - 1/75
M. W. Kellogg	650/2-75-033	Particulate Collection Efficiency Measurements on Wet Electrostatic Precipitators - 3/75
M. W. Kellogg	600/2-75-056	Particulate Collection Efficiency Measurements on Three Electrostatic Precipitators 10/75
Meteorology Research	600/2-75-074	Evaluation of a Particulate Scrubber on a Coal Fired Utility Boiler - 11/75
Midwest Research	600/2-75-020	Particulate Removal from Gas Streams at High Temperature/High Pressure - 8/75
Mitre	600/2-75-037	Test Evaluation of a Cat-Ox High Efficiency Electrostatic Precipitator - 8/75
Textile Research Institute	650/2-75-002	Influence of Fibre Characteristics on Particulate Filtration - 1/75
Aerotherm	600/2-76-052	Impact of Clean Fuels Combustion on Primary Particulate Emissions from Stationary Sources - 3/76

TABLE C.6 (Continued)

Contractor	EPA Report No.	Report Title and Date
Aerotherm	600/7-76-010	Symposium on Particulate Control in Energy Processes - 9/76
A.P.T. Inc.	600/2-76-200	Study of Horizontal Spray Flux Force/ Condensation Scrubber - 7/76
A.P.T. Inc.	600/2-76-154a	A.P.S. Electrostatic Scrubber Evaluation - 6/76
A.P.T. Inc.	600/2-76-282	National Dust Collector Model 850 Variable Rod Model Venturi Scrubber Evaluation - 12/76
Battelle	600/2-76-002	Control of Reclaimation (sinter) Plant Emissions Using Electrostatic Precipitators - 1/76
GCA	600/2-76-055	Evaluation of Electrostatic Augmentation for Fine Particle Control - 3/76
GCA	600/2-76-035	Evaluation of Eight Novel Fine Particle Collection Devices - 2/76
GCA	600/2-76-077a	Fractional Efficiency of a Utility Boiler Baghouse: Sunbury Steam-Electric Station 3/76
Harvard University	600/2-76-020	High Velocity, High Efficiency, Aerosol Filtration - 1/76
IERL-RTP	600/2-76-168a	EPA Fabric Filtration Studies: 1: Performance of Non Woven Nylon Filter Bags 12/76
IERL-RTP	600/2-76-168b	EPA Fabric Filtration Studies: 2: Performance of Non Woven Polyester Filter Bags - 6/76
IERL-RTP	600/2-76-168c	EPA Fabric Filtration Studies: 3: Performance of Filter Bags Made from Expanded PTFE Laminate - 12/76

TABLE C.6 (Continued)

Contractor	EPA Report No.	Report Title and Date
IERL-RTP	600/7-76-027	Effect of Fly Ash Conditioning Agent on Power Plant Emissions - 10/76
Midwest Research	600/2-76-041	Evaluation of Electric Field Fabric Filtration - 2/76
Midwest Research	600/2-76-001	Evaluation of Sonics for Fine Particle Control - 1/76
Midwest Research	600/2-76-066	Evaluation of Turbulent Agglomeration for Fine Particle Control - 3/76
Midwest Research	600/2-76-067	Evaluation of Thermal Agglomeration for Fine Particle Control - 1976
Midwest Research	600/7-76-133	Evaluation of Magnetics for Fine Particle Control - 5/76
Monsanto	600/2-76-042	Particulate Control Mobile Test Units: First Years' Operation - 2/76
Monsanto	600/2-76-125	Application of Foam Scrubbing to Fine Particle Control, Phase I - 5/76
Southern Research Institute	600/2-76-142	Wet Electrostatic Precipitator System Study - 5/76
Southern Research Institute	600/2-76-280	Particulate Sizing Techniques for Control Device Evaluation Cascade Impactor Calibrations - 10/76
Southern Research Institute	600/2-76-140	Rapping Reintrainment in a Nearly Full-Scale Pilot Electrostatic Precipitator - 5/76
Southern Research Institute	600/2-76-141	Particulate Collection Efficiency Measurements on an Electrostatic Precipitator Installed on a Paper Mill Recovery Boiler - 5/76

TABLE C.6 (Continued)

Contractor	EPA Report No.	Report Title and Date
Southern Research Institute	600/7-76-016	Conference on Particle Collection Problems in Converting to Low Sulfur Coals - 10/76
TRW	600/2-76-249a	Charged Droplet Scrubber for Fine Particle Control: Laboratory Study - 9/76
TRW	600/2-76-249b	Charged Droplet Scrubber for Fine Particle Control: Pilot Demonstration - 9/76
TVA	600/7-76-021	TVA's 1-MW Pilot Plant: Verticle Dust Mist Elimination Testing Program - 10/76
University of Washington	600/2-76-100	Univ. of Washington Electrostatic Spray Scrubber Evaluation - 4/76
Aerotherm	600/2-77-067	Evaluation of Molten Scrubbing for Fine Particulate Control - 3/77
Aerotherm	600/2-77-067	Evaluation of Ceramic Filters for High Temperature/High Pressure Fine Particulate Control - 2/77
A.P.T. Inc.	600/7-77-002	Effects of Temperature and Pressure on Particle Collection Mechanisms: Theoretical Review - 1/77
A.P.T. Inc.	600/7-77-071	High Temperature and High Pressure Particulate Control Requirements - 7/77
IERL-RTP	600/7-77-095a	EPA Fabric Filtration Studies: 4: Bag Aging Effects - 8/77
IERL-RTP	600/2-77-197	Evaluation of Foam Scrubbing as a Method for Collecting Fine Particulate - 9/77
IERL-RTP	600/7-77-042	EPA Research in Fabric Filtration Annual Report on IERL-RTP In-House Programs - 5/77
Mitre	600/7-77-013	EPA and ERDA High Temperature/High Pressure Particulate Control Programs - 2/77

TABLE C.6 (Continued)

Contractor	EPA Report No.	Report Title and Date
Monsanto	600/2-77-042	Particulate Control Mobile Test Units: Second Years' Operation - 1/77
Monsanto	600/2-77-110	Application of Foam Scrubbing to Fine Particle Control, Phase II - 6/77
PEDCo	600/2-77-006	Electrostatic Precipitator Malfunctions in the Electric Utility Industry - 1/77
RTI	600/2-77-002	Comparative U.S./USSR Tests of a Hot-Side Electrostatic Precipitator - 1/77
Southern Research Institute	600/2-77-084	Recent USSR Literature on Control of Particulate Emissions from Stationary Sources - 4/77
TVA	600/7-77-019	TVA's 1-MW Pilot Plant: Final Report on High Velocity Scrubbing and Vertical Dust Mist Elimination - 3/77
University of Illinois, Urbana	600/2-77-055	Electric Curtain Device for Control and Removal of Fine Particles - 2/77

TABLE C.7 REPORTS ON ECONOMIC, ENERGY AND RESOURCE CONSERVATION OR RECOVERY FACTORS CONNECTED WITH CONVENTIONAL COMBUSTION SOURCES

Contractor	EPA Report No.	Report Title and Date
M. W. Kellogg	APTD 0689	Economic Evaluation of Metal Oxide Processes for SO_2 Removal from Power Plant Flue Gases - 3/70
TVA	APTD 0615	Sulfur Oxide Removal from Power Plant Stack Gas: Conceptual Design and Cost Study: Ammonia Scrubbing - 1970
TYCO Lab	APTD 1156	Development of the Catalytic Chamber Process [for Manufacture of H_2SO_4 and HNO_3 from Waste Flue Gas] - 10/70
West Virginia University	APTD 0613	Study for the Potential for Recovering Unreacted Lime from Limestone Modified Fly Ash by Agglomerate Flotation - 5/70
Aerospace	APTD 1068	Technical and Economic Factors Associated with Fly Ash Utilization - 7/71
Babcock & Wilcox	APTD 0967	Conceptualized Fly Ash and SO_2 Scrubbing System with By-Product Recovery - 1/71
TVA	APTD 0699	Sulfur Oxide Removal from Power Plant Stack Gas: Conceptual Design and Cost Study: Reactivities of Limestone - 1971
West Vaco	[none]	Development of an Activated Charcoal SO_x Sorption and Sulfur Recovery Process - 6/71
Hittman Assoc.	APTD 0919	Cost Nomographs of Selected SO_2 Abatement Methods - 1/72
M. W. Kellogg	APTD 1104	Detailed Cost Breakdown for Selected Sulfur Oxide Control Processes - 3/72
TVA	APTD 1137	Sulfur Oxide Removal from Power Plant Stack Gases: Conceptual Design and Cost Study: Effect of Organic Acids on Wet Limestone Process - 2/72

TABLE C.7 (Continued)

Contractor	EPA Report No.	Report Title and Date
Tyco Lab	R2-72-038	Development of the Catalytic Chamber Process [for Manufacture of H_2SO_4 and HNO_3 from Waste Flue Gas] - 9/72
Catalytic Inc.	R2-73-148a	Process Cost Estimate for Limestone Slurry Scrubbing of Flue Gas - 1/73
Catalytic Inc.	R2-73-148b	Process Cost Estimate for Limestone Slurry Scrubbing of Flue Gas, Part II -- Detailed Estimate Sheets - 1/73
TVA	R2-73-244	Sulfur Oxide Removal from Stack Gas: Conceptual Design and Cost Study: Magnesia Scrubbing-Regeneration, Prod. of Concentrated H_2SO_4 - 5/73
TVA	650/2-73-051	Marketing H_2SO_4 from SO_2 Abatement Sources -- The TVA Hypothesis - 12/73
Aerotherm	650/2-74-123	Boiler Modification Cost Survey for SO_x Control by Fuel Substitution - 11/74
KVB Engrg.	650/2-74-078a	Field Testing: Application of Combustion Modifications to Control Pollutant Emissions from Industrial Boilers - 10/74
M. W. Kellogg		Availability of Supplies, Materials, and Equipment Needed for Electrostatic Precipitators - 9/74
M. W. Kellogg	650/2-74-098	Evaluation of Investment R&D Alternatives for SO_x Air Pollution Control Processes - 9/74
Aerotherm	600/2-75-046	NO_x Combustion Control Methods and Costs for Stationary Sources: Summary Study - 9/75
Battelle	600/2-75-073	SO_2 Reduction in Non-Utility Combustion Sources -- Technical and Economic Comparison of Alternatives - 10/75

TABLE C.7 (Continued)

Contractor	EPA Report No.	Report Title and Date
TVA	600/2-75-006	Detailed Cost Estimates for Advanced Effluent Desulfurization Processes - 1/75
Wisconsin Electric	650/2-75-045	Stone and Webster/Ionics SO_2 Removal and Recovery Process - 5/75
Acres American	600/2-76-078	Cost Estimating Methodology for Once-Through Cooling Water Discharge Modifications - 3/76
Aerospace	600/2-76-024	Reuse of Power Plant Desulfurization Waste Water - 2/76
Aerotherm	600/2-76-097	Feasibility of a Heat and Emission Loss Prevention System for Area Source Furnaces 4/76
N.B.S.	650/2-74-125	Pollutant Analysis Cost Survey - 12/76
PEDCo	600/2-76-150	Simplified Procedures for Estimating FGD System Costs - 6/76
TRW	600/2-76-093b	Field Testing Sampling/Analytical Strategies and Implementation Cost Estimates: Coal Gasification & FGD - 4/76
West Vaco	600/2-76-135a	Development of the West Vaco Activated Carbon Process for SO_x Recovery as Elemental Sulfur - 5/76
West Vaco	600/2-76-135b	Development of the West Vaco Activated Carbon Process for SO_x Recovery as Elemental Sulfur, Vol. II - 5/76

TABLE C.8 REPORTS ON MULTI-MEDIA IMPACTS AND GOALS RELATIVE TO CONVENTIONAL COMBUSTION SOURCES

Contractor	EPA Report No.	Report Title and Date
Monsanto	600/2-76-176	Air, Water, and Solid Residue Prioritization Models for Conventional Combustion Sources - 7/76
Monsanto	600/2-76-032a	Source Assessment: Prioritization of Stationary Air Pollution Sources -- Model Description - 2/76
Monsanto	600/2-76-032e	Source Assessment: Prioritization of Stationary Air Pollution Sources: Severity of Stationary Air Pollution Sources - 2/76
Monsanto	600/2-77-107c	Source Assessment: Overview Matrix for National Criteria Pollutant Emissions - 7/77

APPENDIX D

SUMMARY OF CURRENT ACTIVITIES

APPENDIX D

SUMMARY OF CURRENT ACTIVITIES

This Appendix presents in tabular form a summary of recent and current project activities in pollution assessment from conventional (stationary) combustion sources. The methods by which this information was gathered have been discussed in Section 6.0 of this report. For convenience these tables are grouped to correspond to the categories of project activity as shown in Table D.1.

Table D.1. Relation of Tables in APPENDIX D to Sections of This Report.

Table Number	Report Section
D.2	VI E.1
D.3	VI E.2
D.4	VI E.3
D.5	VI E.4
D.6	VI E.5
D.7	VI E.6
D.8	VI F
D.9	VI G
D.10	VI H
D.11	VI I
D.12	VI J
D.13	VII B
D.14	VII C
D.15	VII D
D.16	VII E

Brief descriptions of many project activities have been given in Sections 6 and 7 and will not be repeated in this Appendix. As pointed out in Section 6 this listing of projects is not comprehensive, but merely representative of the extensive research activity on the assessment of pollution from conventional combustion sources.

TABLE D2. RESEARCH PROJECTS ON MULTI-SOURCE EMISSIONS MEASUREMENTS

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	3/77-12/79	743K	68-02-2629 Battelle	Environmental Assessment of Afterburner Combustion Systems
EPA	3/77- 1/80	3815K	68-02-2197 TRW Inc.	E/A of Conventional Combustion Systems
EPA	5/76- 5/79	706K	68-02-2155 Catalytic	Environmental Assessment of the Uses of Residual Oil
EPA	2/77-10/79	2727K	68-02-2160 Acurex/ Aerotherm	Environmental Assessment and Systems Analysis of Stationary Source Combustion Control Technology (NO_x)
EPA	5/74- 5/78	1400K	68-02-1415 Exxon	The Effect of Combustion Modification on Pollutants and Equipment Performance of Power Generation Equipment

TABLE D3. RESEARCH PROJECTS ON EMISSIONS FROM UTILITY SOURCES

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	1/76-12/79	750K (to date)	DXE 721 BB TVA	Characterization of Effluents from Coal-Fired Utility Boilers
TVA	FY76	10K	988-15-990-1020 TVA, Chatt.	Trace Element Study
EPA	FY76	180K	68-02-2272 Southern Res. Inst.	Identification and Measurement of High M.W. Organic Compounds from Power Plants
EPA	FY76	120K	77-ABL-04 Southern Res. Inst.	Identification and Measurement of High M.W. Organic Compounds in Emissions from Power Plants and Oil Refineries
EPA	FY76	75K	4026 Brookhaven N.L.	Studies to Determine SO_2 and SO_4 in Power Plant Stack Emissions
ERDA	FY76	66K	AA 06020111 Univ. of N.H.	Investigation of the Mechanisms of Fly-Ash Formation in Coal-Fired Utility Boilers
ERDA	FY76	281K	W-7405-ENG-48 California Univ.	Trace Contaminants from Fossil Fuel Power Stations
ERDA	FY76	66K	W-7405-ENG-82 Ames Labs, Iowa	Characterization of Gaseous Molecular Pollutants Emitted by Energy Generation Sources

TABLE D4. RESEARCH PROJECTS ON EMISSIONS FROM INDUSTRIAL SOURCES

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	6/77-	161K	68-02-2643 IGT	Evaluation of Pollutant Emissions from Industrial Burners Using "Dirty" Low and Medium BTU Gases
EPA	3/77- 7/79	744K	68-02-2627 Battelle	Evaluation of Emissions and Control Technology for Industrial Stoker Boilers
EPA	1/76- 1/77	798K	68-02-2144 KVB Engr. Inc.	Field Testing--Comb. Modifications of Ind. Combustion Equipment
EPA	FY76	315K	CRB-727 KVB Engr. Inc.	Systems Evaluation of the Use of Low Sulfur Western Coal in Existing Small and Intermediate Size Boilers
EPA	FY76	68K	68-02-1500 Ultrasystems Inc.	Low Emission Burners for Package Boilers
EPA	FY76	8K	68-02-1821 Institute of Gas Technology	A Survey of Emissions Control Combustion Equipment Data in Industrial Process Heating
EPA	FY76	400K	68-02-1488 Ultrasystems Inc.	Development of Scale-Up Criteria for Burner Design and Application to Industrial Utility Boilers

TABLE D5. RESEARCH PROJECTS ON EMISSIONS FROM COMMERCIAL, INSTITUTIONAL AND RESIDENTIAL SOURCES

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	1/77- 8/78	542K	68-02-2174 Rockwell/ Rocketdyne	Design Optimization, Construction and Field Optimization of Integrated Residential Furnace
EPA	FY76	60K	CRB-717 EPA-RTP	Characterization and Design Evaluation for Commercial Combustion Systems
EPA	FY76	38K	68-02-1819 Rockwell/ Rocketdyne	Oil Furnace System Optimization - Residential
EPA	FY76	25K	68-02-1848 Battelle	Evaluation of Emissions from Residential and Small Commercial Stoker Coal-Fired Boilers Under "Smokeless" Operation
EPA	FY76	2K	68-02-0251 Battelle	Investigation of the Effect of Combustion Parameters on Emissions from Residential and Commercial Heating Equipment
ERDA			U. Cal.	

TABLE D6. RESEARCH PROJECTS ON FUEL CHARACTERIZATION

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	5/76- 9/77	225K	DXE 685 EJ LASL	Trace Element Characterization and Removal/ Recovery from Coal and Coal Wastes
EPA	5/77- 5/79	457K	68-02-2638 Westinghouse	Analytical Support--Residual Oil
EPA	9/76-10/78	631K	68-02-2187 Battelle	Combustion of Hydrothermally Treated Coal
EPA	8/74- 7/77	395K	R803242 MIT	Combustion Research on Coal Nitrogen and Particulate Organic Matter
EPA	3/76- 4/79	105K	R804403 Univ. Ill. Geol. Survey	Mineral Matter in Coal
EPA	FY76	65K	R-803715-02 Arizona Univ.	Effect of Fuel Sulfur on NO Formation in Combustion Processes
EPA	FY76	60K	CB-745 EPA-IERL	Characterization of Emission and Combustion Performance of Alternate Fuels
EPRI	1977-81	1500K	RP-983 SAI/McNally	Non-Destructive Assay of Coal

TABLE D7. RESEARCH PROJECTS ON MEASUREMENT METHODS

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	3/76- 3/79	899K	68-02-2150 A. D. Little	Sampling and Analysis Methods for POM and Other Organic Pollutants
EPA	12/75-12/78	716K	68-02-2133 Res. Corp. New England	Development of Measurement Techniques for Fugitive Emissions from Process and Effluent Streams
EPRI	1975-77	165K	RP-631 Stanford Univ.	Characterization of Flyash by Auger Electron Spectroscope
EPRI	1977-79	400K	(RFP)	Trace Element Measurement Guidelines
EPRI	1977-78	300K	(RFP)	POM Source Measurement Technology

TABLE D8. RESEARCH PROJECTS ON TRANSPORT AND FATE OF POLLUTANTS

Sponsor	Period	Funding	Contract No. Organization	Description
ERDA	FY76	75K	EAB-540-77-ADA-1 Maryland Bureau of Air Quality Control	Airborne Monitoring Study: Hyperbolic Cooling Tower Effluents and Reactions
ERDA	FY76	150K	ANL 57504 Argonne Nat. Lab.	Atmospheric Particle Chemistry and Sulfur Emission Control Studies
ERDA	FY76	270K	E (30-1)-16 Brookhaven Nat. Lab.	Plume Studies
ERDA	FY76	138K	001781 ERDA	Non-Nuclear Pollutants in Surface Air
EPA	FY76	174K	77BDL TVA	Atmospheric Transformation of Emissions from Coal Fired Power Plants. a) Full Scale Studies
ERDA	FY76	477K	W-7405-ENG-48 California U.	Multistate Atmospheric Power Production Pollution Study (MAP3S)
EPA	FY76	89K	68-02-1873 United Aircraft Corp.	Investigation of Aerodynamic Phenomena in Pollution Control

TABLE D8. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	150K	77ACP-A5 Washington U. St. Louis	Sulfur Budget in Large Plumes
EPA	FY76	-	77AE1-3 Florida St. U.	Mesoscale Sulfur Balance Studies
EPA	FY76	-	77ACO-A3 Texas Univ.	Reactions of SO_2 in Aerosols
EPA	FY76	30K	77 ACP-D Maryland Univ.	An Investigation of OH Reactions of Importance in the Perturbed Troposphere and an Investigation of Trace Gases and Particulates in Oil Fired Power Plant Plumes
EPA	FY76	190K	BAA/70930-32 NOAA, Boulder	Lidar Techniques for Measuring Particulate Pollutants and Their Transport and Dispersion Processes
ERDA	FY76	66K	W-7405-ENG-48 California U.	Formation of Oxyacids of Sulfur from SO_2
ERDA	FY76	35K	E(11-1)2161 Wisconsin Univ.	Energy Generation and the Sulfur Cycle

TABLE D8. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
ERDA	FY76	80K	W-7405-ENG-26 Oak Ridge Nat. Lab.	CUMEX Index and Transport Models for Environmental Pollutants
ERDA	FY76	55K	E(40-1)Gen242 UT-ERDA	Development of Transport Models for Environmental Pollutants
ERDA	FY76	100K	E(45-1) 1830 Battelle	Urban Pollutant Characterization, Transport and Deposition
ERDA	FY76	109K	E(45-1) 1830 Battelle	Precipitation Scavenging in MAP35
ERDA	FY76	426K	W-31-109-ENG-48 Argonne Nat. Lab.	Energy Related Environmental Research on the Great Lakes: Fate and Effects of Non-Nuclear Pollutants
ERDA	FY76	105K	4060 Los Alamos Sci. Lab.	Ecological Fate and Effects of Trace Contaminants from Coal Combustion and Processing

TABLE D8. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
ERDA	FY76	65K	AEC-014-77-E1-AR-1 Nat. Marine Fisheries Serv.	Impacts Associated with Offshore Power Plants: Transport and Fate of Ni, Cu and Zn in Coastal Waters of N.C.
ERDA	FY76	130K	004160 DuPont & Co.	Trace Metal Cycling and Effects on Terrestrial Ecosystems in the Southeast U.S.
ERDA	FY76	270K	E(30-1)-16 Brookhaven Nat. Laboratory	Plume Studies
ERDA	FY76	200K	W-7405-ENG-26 Oak Ridge Nat. Lab.	Environmental Fate of Pollutants from Coal Combustion Plants
EPA	FY76	225K	78 AEI EPA - Denver	Northern Great Plains and Central Rockies Air Quality Baseline Network
EPA	FY76	200K	77 ABG-01 EPA - Las Vegas	Regional Ambient Air Monitoring of Energy Related Toxic Substances and Suspended Particulates in the Southwestern U.S.

TABLE D8. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	125K	78 AEG EPA - Las Vegas	Energy Related Water Monitoring Data Integration
EPA	FY76	450K	77 ABF-01 EPA - Las Vegas	Ambient Air Monitoring in the Vincinity of Energy-Related Sources/Western Energy Development
EPA	FY76	125K	78 ABQ EPA - Cinn.	Standardization and Quality Assurance for Water Monitoring
EPA	FY76	250K	77 ABP-01 Rockwell	Develop and Maintain Interlaboratory Quality Assurance Program for Air Monitoring Laboratories

TABLE D9. RESEARCH PROJECTS ON HEALTH EFFECTS

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	1/77- 9/77	57K	68-02-2625 H2M Corp.	Effects of Pathogenic and Toxic Materials Transported Via Cooling Device
EPA	FY76	166K	ABW-2 Akron Univ.	Determine Behavioral, Physiologic and Metabolic Effects for Populations Residing in Communities where Major Shifts in Pollutants are Anticipated from Coal Conversion or Combustion
EPA	FY76	115K	77ABU-04 Cincinnati U.	Chemical Characterization and Toxicity of Metal Binding Components of Emissions from Mobil and Stationary Energy Sources
EPA	FY76	(?)	77ABV-05 Cincinnati U.	Electroencephalographic and Behavioral Studies of Rats During Long Term Continuous Exposure to SO_2 and Particulate Matter
EPA	FY76	87K	77ABV-06 UCLA School of Medicine	Effects of Pollutants from Energy Consumption and Environmental Trace Metals on Lung Metabolism
EPA	FY76	86K	ABW-2d Maryland U.	Study the Effects on Asthmatics of Pollutants Resulting from Converting to Coal Combustion in a Power Plant

TABLE D9. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	100K	77-AEE-2-4 Northrop Services Inc.	Cytotoxicity Evaluation of Selected Sulfates and of Source and Ambient Air Samples
EPA	FY76	130K	77ABV Battelle	Investigation of Effects of Prolonged Inhalation of Ni, B, and Cr, Envriched Western Coal Fly Ash in Syrian Golden Hampsters
EPA	FY76	90K	77ABX-3-2 IIT Res. Inst.	Evaluate Effects of Chronic or Intermittent Exposure to Respirable Particles and Mists Using Mouse Pulmonary Infectivity Model
EPA	FY76	69K	77-ABV-01/02 EPA	Comparative Toxicological Assessment of Fly Ash from Western and Eastern Coal
EPA	FY76	193K	77-ACE-3 Geomet, Inc.	Study the Health Effects of NO_2, CO, and HC, from Newly Insulated Homes
ERDA	FY76	67K	E(40-3)-472 California U.	Assessment of Health Effects of Energy Systems
ERDA	FY76	224K	W-7405-ENG-48 California U.	Trace Elements in Major Food Chains

TABLE D9. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
ERDA	FY76	100K	4117 Battelle	Toxicity of CO, NO_x, SO_x, and Fly Ash
ERDA	FY76	111K	4052 Lovelace Found.	Metabolism of Inhaled Trace Metal Effluents
ERDA	FY76	-	4118 Battelle	Lung Toxicity of Sulfur Pollutants
ERDA	FY76	80K	4119 Battelle	Factors Influencing Cross-Placental Transfer and Teratogenicity of Metallic Pollutants
ERDA	FY76	141K	4056 Lovelace Found.	Develop Instrumentation and Methods to Identify, Measure, and Analyse Energy Related Aerosols and Particulates in Relation to Direct Effects on Health
EPRI	1980-82	2500K	-	Measurement Support for Determining Utility Impact on Health and Welfare Issues
NIEHS	FY76	33K	R01-ES01045 California U.	Biochemical Effects and Reactions of SO_2

TABLE D9. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
NIEHS	FY76	(?)	R01-ES00852 UCLA School of Medicine	Environmental Trace Metal Intoxications of the Kidney
NIEHS	FY76	34K	R01-ES00839 Bowman Gray School of Med.	Effect of NO_2 Induced Lesions in Lung Macrophages
NIEHS	FY76	69K	R01-ES00827 Harvard Univ.	Factors Affecting Irritant Potency of Gases and Aerosols
NIEHS	FY76	(?)	R01-ES00741 Johns Hopkins University	Interraction of SO_2 and Virus on Respiratory Mucosa
Public Health Service	FY76	236K	EPA-1AG-05-E773-CX-6 Appalachian Lab for Occupational Resp. Disease	Mortality Study of TVA High Risk Workers
NIOSH	FY76	155K	(?) NIOSH	Sulfuric and Acid Sulfates, Occupational Health Epidemiological Study

TABLE D10. RESEARCH PROJECTS ON ECOLOGICAL EFFECTS

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	125K	EPA-TAG-E693 NOAA, Boulder	Cloud and Precipitation Modification Effects of Pollutants from Energy Production
EPA	FY76	184K	77BDO TVA	Characterize and Quantify the Transfer, Fate and Effects of SO_x, NO_x, and Acid Precipitation in the Terrestrial Ecosystem Representative of the Tennessee Valley
EPA	FY76	150K	77BDO TVA	Fillered and Filtered/Unfiltered Exposure Chamber Studies of Effects of Coal-Fired Power Plant Emissions on Crop and Forest Species of Economic Importance in the Southeastern U.S.
EPA	FY76	45K	77BDO TVA	Determine Dose Response Kinetics for Effects of Atmospheric Emissions from Coal Fired Power Plants on Soybeans and Other Crop and Forest Species
EPA	FY76	44K	77BDO TVA	Evaluate the Beneficial Effects of SO_2 and Other Pollutants Emitted from Steam Plants on Crop Species and Forests, Particularly Soybeans and Pines
EPA	FY76	110K	68-02-1319 Radian Corp.	Technical Support for Environmental Problem Definition and Pollutant System Studies

TABLE D10. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	193K	R804008-2 Battelle	Environmental Effect of Utilizing Solid Waste as a Supplementary Power Plant Fuel
EPA	FY76	100K	77ACO-D Rockwell Inc.	Study the Effects of Airborne Sulfur Pollutants on Materials
ERDA	FY76	91K	6815 Penn. St. Univ.	Field Measurement of the Environmental Impact of Evaporative Cooling Tower Plumes
ERDA	FY76	71K	E(04-1)Gen-12 California U.	Effects of Non-Nuclear Pollutants on Arid Environments
ERDA	FY76	51K	W-7405-ENG-48 California U.	Effects on California Marine Biota of Effluents from Power Plants: Laboratory Studies
ERDA	FY76	130K	E(11-1)3279 Johns Hopkins U.	The Effects of Energy Related Activities on the Plankton in the Chesapeake Bay
ERDA	FY76	80K	E(11-1)2726 State Univ. Coll.	Environmental Impact of Coal Ash on Tributary Streams and Near Shore Waters of Lake Erie
ERDA	FY76	75K	7128 Rand Corp.	Investigation of Environmental Effects Caused by Rejection of Waste Heat from Large Electric Power Plants Directly into the Atmosphere

TABLE D10. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
ERDA	FY76	426K	W-31-109-ENG-48 Argonne Nat. Lab.	Energy Related Environmental Research on the Great Lakes: Fate and Effects of Non-Nuclear Pollutants
ERDA	FY76	147K	000601	Land and Freshwater Environmental Sciences: Impact of Fossil Fuel on Terrestrial Ecosystems
ERDA	FY76	176K	E(30-1)-16 Brookhaven Nat. Lab.	Effects of Acid Rain on Terrestrial Ecosystems
ERDA	FY76	231K	AT(07-2)-1 DuPont & Co.	Thermal Effects Program
ERDA	FY76	105K	4060 Los Alamos Sci. Lab.	Ecological Fate and Effects of Trace Contaminants from Coal Combustion and Processing
ERDA	FY76	(?)	4112 Battelle, Pac. N.W.	The Immediate Effects of Effluents from Coal Utilization on the Behavior and Physiology of Freshwater Biota

TABLE D10. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
ERDA	FY76	65K	AEC-014-77-E1-AR-1 Nat. Marine Fisheries Serv.	Impacts Associated with Offshore Power Plants: Transport and Fate of Ni, Cu, and Zn in in Coastal Waters of N.C.
ERDA	FY76	$100	004114 Battelle	Power Plant Heat and Chemical Effluent Effects on Selected Marine and Estuarine Communities
ERDA	FY76	130K	004160 DuPont & Co.	Trace Metal Cycling and Effects on Terrestrial Ecosystems in the Southeast U.S.
ERDA	FY76	148K	001345 Argonne Nat. Lab.	Assessment of the Environmental Condition of the Great Lakes in Relation to Power Production
ERDA	FY76	90K	W-7405-ENG-06 Oak Ridge Nat. Lab.	Environmental Effects of Cooling Tower Drift
ERDA	FY76	69K	W-7405-ENG-26 Oak Ridge Nat. Lab.	Ecological Effects of Coal Combustion: Response of Vegetation to SO_2, O_3 and Acid Precipitation

TABLE D10. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
NOAA	FY76	11K	04-6-158-44021 California U.	Biological Effects of Waste Heat Effluents from Coastal Power Plants
Dept. of Commerce	FY76	55K	(?) Environmental Res. & Tech. Inc.	Environmental Energy Consumption of the Fossil Fuel Steam Electric Generating Industry
	FY76	1575K	(?) TVA	Fisheries Impacts of Steam Electric Power Plant Operation
EPA	1975-1978	-	R803971010 U. Wisconsin	The Impact of Coal Fired Power Plants on the Environment

TABLE D11. RESEARCH PROJECTS ON MULTIMEDIA GOALS

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	69K	68-02-1404 Monsanto	Air, Water, and Solid Prioritization Models for Conventional Combustion Sources
EPA	3/77- 9/77	2370K	68-02-2612 RTI	Non-Personal, Quick Reaction, Engineering and Technical Services [Tasks 10, 26 and 27 have been devoted to various aspects of multimedia goals development]
FEA	FY76	75K	CO-04-60470-00 Environmental Res. & Tech.	Technical and/or Policy Evaluation for Air and/or Water Environmental Impacts from Energy Generation and Related Facilities, and from Energy Intensive Industries

TABLE D12. RESEARCH PROJECTS ON ECONOMIC AND ENERGY FACTORS

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	5/75- 9/77	100K	DXE 721 BH TVA	Energy Requirement Optimization Study of Selected Processes for Removing SO_2 from Power Plant Stack Gases
EPA	FY76	350K	77 BBI TVA	Develop Comparative Economics of Major Stack Gas Emission Control Processes
EPA	3/77- 2/78	359K	68-02-2196 Ultrasystems Inc.	Eval. Comb. Design Concepts for Advanced Low BTU Gas Fired System
EPRI	1977-79	900K	RP-1031 (RFP)	Chemistry Modifications to Improve Reliability and Cost
EPRI	1977	200K	RP-783-2 Stearns-Roger	Technical/Economic Evaluation of NO_x Post Combustion Control Alternatives
EPRI	FY76	17K	(?) TVA	Economic Study of Dry NO_x Removal
TVA	FY76	2K	988-15-990-6009 TVA	Beneficial Use of Waste Heat: General
	FY76	55K	(?) Environmental Res. & Tech.	Environmental Energy Consumption of the Fossil Fuel Steam Electric Generating Industry

TABLE D13. RESEARCH PROJECTS ON SO_2 CONTROL TECHNOLOGY

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	5/75- 9/78	250K	DXE 681 BV ERDA-GFERC	Develop FGD Technology-Alkaline Ash Scrubbing
EPA	5/75- 9/79	100K	DXE 685 DA USBM	Demonstration of the Citrate Process FGD System
EPA	2/76- 3/80	375K (to date)	DXE 721 BA TVA	Processing Sludges from Lime/Limestone Wet Scrubbing, etc.
EPA	6/75-12/77	599K	68-03-2334 A. D. Little	Evaluation of Alternatives for Disposal of FGD Sludges
EPA	3/77- 7/78	223K	68-02-2633 Aerospace	Study of Disposal of By-Products from Non-Regenerable FGD Systems
EPA	6/77-	1415K	68-02-2634 Bechtel	Test Program for the Full Scale Double Alkali FGD Utility Demonstration
EPA	9/76-1/80	4500K	68-02-2189 Louisville Gas & Elec.	Full Scale Utility Double Alkali Demo

TABLE D13. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	9/76– 7/77	2083K	68-02-2195 Empire State Energy Res. Corp.	Advanced Regenerable FGD Demo
EPA	4/77– 8/77		68-01-3528 Aerospace Corp.	Assessment of Effects of More Stringent NSPS for Power Plant SO_2 Emissions
EPA	3/77–10/77		68-01-4147 PEDCo	Survey of Utility FGD Systems
EPA	3/76– 9/77	1800K	68-02-2143 Louisville Gas & Elec.	LG&E Full-Scale Scrubber Testing and Waste Disposal Program
EPA	6/76– 5/78	150K	R804531 Auburn Univ.	Dewatering Principles and Equipment Design Studies
EPA	FY76	60K	68-02-2102 Radian Corp.	Engineering and Analytical Support for the Louisville Gas & Electric Scrubber Test Program
EPA	FY76	450K	77 BAZ TVA, Chattanooga	Lime/Limestone and Advanced Concepts: TVA's 1-MW Pilot Plant (Colbert)

TABLE D13. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	(?)	77 BBK TVA, Muscle Shoals	Development of FGD Technology Pilot Plant Study of the Ammonia Absorption-Ammonium Bisulfite Regeneration Plant
EPA	FY76	799K	68-02-1814 Bechtel Corp.	Shawnee Prototype Study of Lime/Limestone Scrubbing - Advanced Testing and Data Evaluation
EPA	FY76	160K	68-02-2171 Resources Cons. Co.	Effective Control of Secondary Water Pollution from FGD Systems
EPA	FY76	363K	68-02-1010 Aerospace Corp.	Study of Disposal of By-Products from Non-Regenerable FGD Systems
EPA	FY76	28K	68-02-2988 TRW, Inc.	Technical Assessment of Air Pollution Control for SO_x and NO_x and Other Emissions at Baltimore Demonstration Facility
EPA	FY76	50K	77 BBH TVA, M.S.	Energy Requirement Conservation Study of Selected Processes for Removing SO_2 from Power Plant Stack Gases

TABLE D13. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	3250K	77 BBL TVA, M.S.	Development of Flue Gas Desulfurization Technology, Shawnee Lime/Limestone Scrubbing Program
EPA	FY76	100K	77 BBM TVA, M.S.	Advance Concept SO_2 Removal Processes Improvements
ERDA	FY76	100K	800057 Argonne Nat. Lab.	Environmental Control Technology for Generation of Power from Coal
EPRI	FY76	300K	TV-42660A TVA, Chatt.	Development of Improved Lime/Limestone Scrubbing Technology
EPRI	1977-79	600K	(RFP)	Emission/Collection Characterization for Scrubbers
EPRI	1976-78	300K	RP982-1 PEDCo	State of the Art Design Guidelines for Lime/Limestone Scrubbing
EPRI	1977-82	5100K	RP1033 TVA	Commercial System Development and Technical Field Support (Eastern High Sulfur Coal) Shawnee

TABLE D13. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPRI	1977-78	350K	RP 786-2 Envirotech	Evaluation of Sludge Dewatering Processes
EPRI	1976-77	200K	RP 202 So. Cal. Edison & Radian Corp.	Sludge Composition and Leachability
EPRI	1976-77	150K	RP 786-1 Radian &	Sludge Composition
EPRI	1976-77	1500K	RP-784 Stone & Webster	Comparative Design of Advanced Processes [FGD]
EPRI	1977	150K	RP-981 Atomics International	Aqueous Carbonate Process Development (Niagara Mohawk)
EPRI	1978-80	4500K (est)	-	Co-Sponsored Pilot Construction & Operation of Advanced Processes (Regeneration of Sub-Systems)
EPRI	1975-77	450K	RP-536 Southern Serv.	Pilot Test of Chiyoda, Double Alkali, Bergbau Processes

TABLE D13. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPRI	1977	200K	RP-1032 Philadelphia Electric	Demo of Mag.-Ox. Process
EPRI	1980-82	5500K	-	100 MW + Demonstration of Advanced Processes
TVA	FY76	350K	988-15-994-001 TVA, Chatt.	Widow's Creek Unit 8: Limestone Wet Scrubber
TVA	FY76	40K	988-15-990-1014 TVA, Chatt.	SO_x Technology
TVA	FY76	5K	988-15-990-1013 TVA, Chatt.	Sludge Disposal from SO_x and Particulate Removal Processes
FEA	FY76	55K	CO-05-060568-00 Olson Labs Inc.	Assessment of FGD to be Used in Environmental Assessments and EIS's
EPRI	1977-82	3500K	(2 RFP's)	Systems Study of PC Boilers with Cleanup Devices Integrated Emission Control

TABLE D14. RESEARCH PROJECTS ON NO_x CONTROL TECHNOLOGY

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	2/77- 2/80	3271K	68-02-2631 Ultrasystems	Fundamental Combustion Research Applied to Pollution Control
EPA	1/77- 1/78	340K	68-02-2624 Ultrasystems	Effects of Fuel Properties and Atomization Parameters on NO_x Control for Heavy Liquid Fuel Fired Package Boilers
EPA	3/77- 2/78	359K	68-02-2196 Ultrasystems Inc.	Eval. Comb. Design Concepts for Advanced Low Btu Gas Fired System
EPA	1/77- 4/78	277K	68-02-2188 United Techn. Corp.	An Investigation of NO_x, Nitrate and Sulfate Production in Laboratory Flames
EPA	12/75- 4/78	1607K	68-02-2136 United Tech.	Advanced Combustion Systems for Stationary Gas Turbine Engines
EPA	6/76- 7/77		R803283 Aerospace Corporation	Analysis of NO_x Control in Utility Boilers
EPA	6/75-11/77	129K	R803715 U. Ariz.	Effect of Fuel Sulfur on Nitrogen Oxide Formation in Combustion Processes

TABLE D14. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	12/76-12/78	65K	R804740 UNC	Photochemical Study of NO_x Removal by Photochemical Oxidation, etc.
ERDA	FY76	150K	E(45-1)1830 Battelle	Reaction Kinetics of Combustion Processes
EPA	FY76	60K	CRB-725 EPA-IERL	Combustion Control Technology for Conventional Combustion Systems
EPA	FY76	80K	CRB-721 EPA-RTP	Emissions Control Technology for High Pressure Combustion Systems
EPA	FY76	113K	68-02-1360 Inst. Gas Tech.	Burner Design Criteria for Current and Future Gaseous Fuels
EPA	FY76	65K	R-803715-02 Arizona Univ.	Effect of Fuel Sulfur on NO Formation in Combustion Processes
EPA	FY76	50K	TV-37968A TVA, Chatt.	Control of NO_x Formation in Wall, Coal-Fired Utility Boilers

TABLE D14. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	17K	68-02-0292 Environics Inc. Newport, Ca.	Catalytic Reduction of Nitrogen Oxides with Ammonia: Utility Pilot Plant Operation
EPA	FY76	47K	68-02-1486 Combustion Engr. Inc.	Field Test Program to Study Staged Combustion Technology for Tangentially Fired Utility Boilers Using Sub-Bituminous Coal
EPA	FY76	37K	68-02-1074 KVB Engr.	Application of Combustion Modification Techniques to Control Pollutant Emissions from Industrial Boilers
EPRI	1976-78	1550K	RP-899 Babcock & Wilcox	Low NO_x Burner/Boiler Development
EPRI	1979-80	800K	-	25 MW Low NO_x Burner Evaluation
EPRI	1975-78	545K	RP-359 Solar	Low NO_x Gas Turbine Combustor Development
EPRI	1977-78	600K	RP-835 Exxon (Phase I)	Pilot Evaluation of NO_x Decomposition

TABLE D14. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPRI	1977	200K	RP-783-2 Stearns-Roger	Technical/Economic Evaluation of NO_x Post-Combustion Control Alternatives
EPRI	1977-79	1300K	(RFP)	Pilot Evaluation of Catalytic/Scrubbing Methods (1-5 MW)
EPRI	1980-82	6500K	(RFP)	Prototype (30-100 MW) of Integrated Combustion/Post Combustion NO_x Control on Coal Boilers
TVA	FY76	20K	988-15-990-1006 TVA, Chatt.	NO_x Technology

TABLE D15. RESEARCH PROJECTS ON PARTICLE CONTROL TECHNOLOGY

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	1/76- 6/79	210K	DXE 721 BC TVA	Fly Ash Characterization and Disposal
EPA	5/77-	148K	68-02-2641 MWRI	Fine Particle Emissions Information System Development
EPA	3/77- 6/78	259K	68-02-2628 Air Poll. Techn. Inc.	Effects of Conditioning Agents on Emissions from Coal Fired Boilers
EPA	9/76- 3/78	564K	68-02-2193 SRI	Fine Particle/High Res. ESP Development
EPA	9/76- 9/77	153K	68-02-2184 Air Poll. Techn. Inc.	Scrubber Entrainment Separator Development and Test at Pilot Scale
EPA	9/76- 1/78	195K	68-02-2185 SRI	Eval[illegible]n of Hot Side ESPs
EPA	1/77- 7/77	16.3K	68-01-4139 Mid West RI	FPEIS Data Acquisition and Quality Assurance

TABLE D15. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	FY76	65K	R-804233-01 Nashville Thermal Transfer Corp.	Baghouses as Emission Control Devices for Solid Waste Incinerator/Boiler
EPA	8/74- 7/77	395K	R803242 MIT	Combustion Research on Coal Nitrogen and Particulate Organic Matter
ERDA	FY76	250K	AA0602015 ERDA, Grand Forks	Electrostatic Precipitation of High Resistivity Fly Ash in Stack Gases
EPRI	1976-78	900K	RP-780 Met. Research Inst.	Fractional Efficiency and Collection Characterization for ESP
EPRI	1976-78	100K	RP-785 A. D. Little	Low Sulfur Alkaline Ash Scrubbing Characterization
EPRI	1975-77	265K	RP-532 Princeton/Res. Cottrell	Electrostatic Precipitator Plate Rapping and Reliability Analytical Model

TABLE D15. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	2/76- 3/77	190K	R804393 U. Wash.	Fine Particulate Control with U.W. Electrostatic Scrubber
EPA	8/76- 8/79	63K	R804700 Harvard U.	High Velocity Fabric Filtration
EPA	FY76	100K	77 BBC TVA, Chatt.	Fly-Ash Characterization and Disposal
EPA	FY76	$100	68-02-2114 Southern Res. Inst.	Electrostatic Precipitators for Control of Fine Particles
EPA	FY76	108K	68-02-1438 GCA Corp.	Fabric Filtration Measuring and Modeling Program
EPA	FY76	500K	68-02-2148 EPA	Demonstration of a High Efficiency/High Throughput Baghouse
EPA	FY76	102K	68-02-2124 Air Pollution Tech. Inc.	Mobil Bed Flux Force/Condensation Scrubbers

TABLE D15. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPRI	1976-77	377K	RP-629 Babcock & Wilcox	Minicombustor for Electrostatic Precipitator Design Support
EPRI	1976-78	275K	RP-724 So. Res. Inst.	Flue Gas Conditioning for Enhanced Precipitation of Difficult Dusts
EPRI	1976-78	585K	- TVA	Retrofit Application of High Intensity Ionizer on Coal Fired Utility Plant
EPRI	1975-82	10350K	RP-725 Pub. Ser. Colo., Con. Ed., Westcon Precip.	Advanced Particulate Control Pilot Plant (Arapahoe) and Technical Field Support
EPRI	1977-78	RFP	RFP	Kramer/Cameo Commercial Utility S.O.A. Fabric Filter (Baghouse) Evaluation
EPRI	1977-81	1800K	RFP	Advanced Fabric Filter Dev. (Arapahoe)
EPRI	1977-78	300K	RFP	Improved Hopper Ash Removal Systems

TABLE D15. (Continued)

Sponsor	Period	Funding	Contract No. Organization	Description
EPRI	1976-82	1200K	RP-725 Stone & Webster	Dev. of Hot Gas Clean-Up System
TVA	FY76	10K	988-15-990-1018 TVA, Chatt.	Particulate Technology

TABLE D16. RESEARCH PROJECTS ON THERMAL POLLUTION

Sponsor	Period	Funding	Contract No. Organization	Description
EPA	1/76-12/79	790K (to date)	DXE 721 BE TVA	Advanced Waste Heat Control
EPA	5/75-12/78	520K (to date)	DXE 721 BF TVA	Waste Heat Utilization
TVA	FY76	30K	988-15-990-1003 TVA, Chatt.	Use of Waste Heat in Sewage Sludge Digestion
ERDA/U.S. Geol. Surv.	FY76	200K	WD-75-058 U.S. Geol. Surv.	Subsurface Heat Storage
EPA	FY76	100K	- No. States Power Co.	Beneficial Uses of Warm Water from Condensers of Electric Generating Plants
ERDA	FY76	84K	- Battelle N.W.	Combined Effects of Waste Heat and Environmental Factors Acting in Concert